



# The Impact of Deep Brain Stimulation for Parkinson's Disease on Couple Satisfaction: An 18-Month Longitudinal Study

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## Abstract

Patients with Parkinson's disease (PD) may benefit from deep brain stimulation (DBS) to improve motor and medication-induced symptoms. Yet mixed evidence regarding the outcome of successful DBS on couple satisfaction has been highlighted in the literature. Thirty patients diagnosed with PD were included in a study investigating couple satisfaction (MSS-14), depression (HAD-D) and anxiety (HAD-A) at four measurement times: before DBS and 6, 12, and 18 months post-surgically. Sixteen spouses/partners were included as well. Couple satisfaction from the patient perspective was never associated with depression or anxiety. However, poor marital adjustment (i.e., difference and absolute difference between patients and spouses/partners MSS-14 scores) predicted patients' pre-operative depressive mood. Longitudinal analyses showed that couple satisfaction ( $n=9$ ) worsened at 12 months and 18 months compared to pre-DBS scores,  $F(2.047, 16.378)=8.723$ ,  $p=.003$ , and despite concomitant motor improvement. Growth curve analyses showed that couple satisfaction worsening occurred between 6 and 12 months post-operatively ( $b=2.938$ ,  $p<.001$ ). Thus, couple satisfaction did not increase along with motor improvement and deteriorated after the adjustment period following DBS.

**Keywords** Couple satisfaction · Parkinson's disease · Deep brain stimulation · Longitudinal

A neurodegenerative condition without curative treatment, Parkinson's disease (PD) affects about 1% of individuals aged 60 and over, and 1–2 per 1000 inhabitants (Tysnes &

Storstein, 2017). The clinical picture is mainly characterized by bradykinesia, tremor, rigidity, and postural instability despite a great variety of individual differences (Jankovic,

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2008). Dopaminergic medication is usually prescribed to address these symptoms; yet the progression of the disease requires regular dosage adaptation, which fosters occurrence of adverse effects notably motor and behavioral (Obeso, Olanow, & Nutt, 2000; Voon & Fox, 2007). Patients with PD have also to face a range of non-motor symptoms, such as depression, anxiety, pain, cognitive impairment, or sexual dysfunction, which may be experienced as extremely disabling in the longer term (Hely, Morris, Reid, & Trafficante, 2005).

An indirect effect of PD, social and interpersonal relationships is impacted by the disease progression. At an advanced stage, patients are forced to reduce or quit their leisure and professional activities, and become increasingly dependent on external aid (Van der Bruggen & Widdershoven, 2004). This requires adaptations in illness management, which has direct consequences on the couple relationship. Illness management has indeed been theorized as a dyadic process in which dyadic appraisal influences both the dyadic and each partner's response to a situation (Lyons & Lee, 2018). These premises have been empirically supported, as progression of PD has been associated with the worsening of the partner's depressive symptoms (Lyons, Stewart, Archbold, Carter, & Perrin, 2004) and patients' symptom management was less efficient in case of heavy caregiver burden (Edwards & Ruettiger, 2002). In line with that, distress in patients and partners positively covaried (Miller, Berrios, & Politynska, 1996). Thus, patients at an advanced stage of PD appear to be caught in a vicious circle in which their increasing symptoms would require a sustained involvement of exhausted caregivers who, for their part, would tend to step down.

Considering the above, difficulties in the couple relationship appear to be strongly related to the symptoms inherent to PD and its associated medication. From this perspective, couple relationship should arguably benefit from improvement of these symptoms. A treatment available when PD symptoms persist despite optimal medical treatment (Pollak, 2013), deep brain stimulation (DBS) refers to a stereotactic neurosurgical procedure in which electrodes are implanted into brain nuclei. This procedure improves motor symptoms, leads to a diminution of dopaminergic medication and its adverse side effects, and ameliorates health-related quality of life (Houeto et al., 2002, 2006; Schüpbach et al., 2006, 2013; Vingerhoets et al., 2002; Williams et al., 2010). In this regard, it could be hypothesized that a significant reduction of PD symptoms brought in by successful DBS surgery would lead to improvement in the perceived quality of the couple relationship.

Interestingly, however, the few studies investigating the quality of couple relationship after DBS for PD have found mixed outcomes. At first sight, satisfaction in the relationship seems to be sustained in the great majority (between 70 and 86% depending on measures) of patients and partners

3 years after surgery (Boel et al., 2016). However, others reported contrasted outcomes after a follow-up of 2 years with feelings of disappointment and clinical symptoms regularly reported by both members of the dyad. Notably, about 20% of patients rejected their spouse (Agid et al., 2006; Schüpbach et al., 2006). In line with the above, two studies assessing couple relationship from a qualitative perspective provided generally positive outcomes 1 year following DBS; yet, these studies also identified a transitional phase taking place within this initial post-operative year where adaptation to life with DBS was associated with strains in the relationship (Haahr, Kirkevold, Hall, & Østergaard, 2010, 2013). In addition, adjustment difficulties within the couple relationship have been reported in patients undergoing surgery for other chronic diseases, such as anterotemporal lobectomy for epilepsy (Bladin, 1992; Wilson, Saling, Kincade, & Bladin, 1998) and ventricular assist device therapy for heart failure (Bidwell et al., 2017, 2018). Overall, these contrasted results suggest that symptom improvement is not the only variable influencing the quality of couple relationship after a medical intervention.

The present study was designed to investigate the longitudinal trajectory of couple satisfaction from the patient perspective, through four measurement points at 0 (i.e., within 2 weeks before DBS), 6, 12, and 18 months following surgery. In light of the mixed results from the literature highlighted above, and the general paucity of existing studies in this particular area, we decided to take an exploratory stance and did not specify research hypotheses.

## Methods

### Participants

Fifty-two patients diagnosed with PD were included between January 31st, 2013 and June 8th, 2017 in a global study investigating the possible determinants of quality of life after DBS at the Geneva University Hospitals. Inclusion criteria were a DBS medical indication for idiopathic PD collaboratively established by a senior neurologist, neurosurgeon, neuropsychologist and consultation-liaison psychiatrist, a French level sufficient to read and understand a series of self-administered questionnaires, and the agreement to sign a consent form. Participation was proposed to all patients clinically accepted for DBS, which includes capacity of discernment, and all agreed with the study procedure. One patient was nevertheless excluded because of a dual diagnosis. For the specific needs of the current study, we only selected patients with PD who were in a couple relationship at inclusion time. As 20 were not in a couple relationship and two did not provided a signed consent form, the final sample consisted of 30 patients (16 males). On average, they

were  $61.41 \pm 6.56$  years old, had been in their current couple relationship for  $31.13 \pm 13.05$  years, and had  $1.80 \pm 1.06$  children. They had had a PD diagnosis for  $9.70 \pm 4.36$  years and were measured with a UPDRS-III (*on medication*) score of  $20.73 \pm 12.08$ . All patients underwent bilateral DBS in the subthalamic nucleus.

In addition, we offered the spouse/partner of each patient to participate to the study, which resulted in the inclusion of 16 spouses/partners.

## Procedure

Patients included in the study were presented with a series of clinician- and self-administered questionnaires at four measurement times, namely at about 2 weeks before DBS (T0), and 6 (T1), 12 (T2), and 18 (T3) months after. The Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS) was completed by a trained nurse or doctor in neurology when patients had taken their dopaminergic medication. Three of these four measurement times (i.e., T0, T2, and T3) were part of the clinical routine in which patients are summoned to the neurology unit for global evaluation. The remaining measurement time (i.e., T1) took place outside this clinical routine and, for this reason, we were unable to administer the MDS-UPDRS at T1. Patients were proposed to fill out three self-administered questionnaires assessing couple relationship from the patient perspective, current anxiety, and current depression. All were either handed in personally by the consultation-liaison psychiatrist responsible for patients' clinical management during a visit to the hospital or sent by mail (notably at T1). In the latter case, patients were asked to mail them back using a stamped envelope provided on this occasion. Spouses/partners filled out a questionnaire of marital satisfaction (MSS-14). However, due to organizational and logistical difficulties, data from spouses/partners were only gathered at T0.

A research assistant was in charge of making a reminder call if questionnaires were not sent back within a week and of directly calling patients, respectively spouses/partners, to supplement missing data. Patients were additionally proposed to answer other questionnaires not relevant for the current study. The present study and its procedure received approval from the Canton of Geneva ethics committee under the registration number 14-182.

## Instruments

Satisfaction in the couple relationship was assessed with the Marital Satisfaction Scale (Roach, Frazier, & Bowden, 1981), which has been translated and validated in French under a 14-item reduced version (MSS-14) (Baertschi et al., 2017). Each item is evaluated with a 5-point Likert scale,

the total score ranging from 14 to 70 points with high scores suggesting satisfaction in the couple relationship. A score of 53 discriminates individuals experiencing or not distress in their relationship. Internal consistency in the current sample was excellent as expressed by Cronbach's alpha ( $\alpha = 0.929$ , 95% CI [0.880, 0.964]). As the MSS-14 was also responded by spouses/partners, two measures of couple adjustment were created by computing the difference (MSS-MA-D) and the absolute difference (MSS-MA-AD) between a patient's and his/her respective spouse/partner's scores.

Anxiety and depression were assessed with the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983). This instrument proposes two subscales evaluating current anxiety (HAD-A) and depression (HAD-D), each comprised of seven items designed with a 4-point Likert scale. For both subscales, the total score ranges from 0 to 21 points and the authors found the probability to have a clinical disorder that corresponds to a score of 8 or above. The French version of the questionnaire has been validated among several populations (e.g., Untas et al., 2009). In our sample, internal consistency was acceptable for the HAD-A ( $\alpha = 0.725$ , 95% CI [0.539, 0.854]) and the HAD-D ( $\alpha = 0.742$ , 95% CI [0.568, 0.863]).

The Movement Disorder Society (MDS) Unified Parkinson's Disease Rating Scale (UPDRS) is a clinician-administered questionnaire examining the severity of PD symptomatology. In this study, we used the third part of the scale that focuses on motor examination and contains 18 items (MDS-UPDRS III). Each item corresponds to a specific motor function, which is assessed through a 5-point Likert scale ranging from 0 (absence of problem) to 5 (severe problem). Thus, low ratings suggest few motor problems. As only the total score was available, we could not obtain a measure of reliability for our sample.

## Statistical Analyses

As a first step, we aimed to investigate the global situation of patients at study inclusion and at every measurement time of the follow-up. In this regard, correlation analyses were conducted among variables of interest.

Second, a range of multiple regression equations were designed to assess the predictive value of the initial (i.e., T0) score of marital satisfaction (MSS-14) for patients and spouses/partners, respectively marital adjustment (MSS-MA-D, MSS-MA-AD), in patients' anxiety (HAD-A) and depression (HAD-D) for every measurement time of the follow-up. All these regression models included a measure of control for the variance of motor symptoms (MDS-UPDRS). An additional measure of control for the initial level of couple satisfaction (estimated with the patient MSS-14 score at T0) was included for marital adjustment analyses. Analyses

at T1 were not carried out because of the unavailability of MDS-UPDRS scores.

Next, longitudinal analyses were conducted to assess the dynamics of couple satisfaction throughout the pre- and post-DBS period. To this end, we conducted a repeated measures analyses of variance (ANOVA) including post-hoc analyses. We also estimated growth trajectory using structural equation modeling, comparing different slope types to establish the model with most optimal adjustment. Additionally, we designed a second repeated measures ANOVA to control for motor improvement as proxy for DBS success. We computed two planned contrasts as we expected; first, to find significant motor improvement at the first post-surgical measurement time (i.e., T2) in comparison with pre-DBS assessment (i.e., T0) and; second, that this improvement would be sustained over time (i.e., no deterioration between T2 and T3).

All statistical analyses were conducted with Statistica version 13.0 (StatsSoft Inc., Tulsa, OK, USA), IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA) and Amos version 23.0 (IBM SPSS, Chicago, IL, USA).

## Results

Univariate analyses of normality included histogram observation and computation of Z scores for skewness and excess kurtosis, following previous recommendation (Kim, 2013). As the distribution of the MSS-MA-AD variable was skewed, we applied a linear transformation followed by a log 10 transformation, which reduced skewness to an acceptable value ( $Z = -0.415$ ). We conducted Pearson's correlation analyses between variables of interest for every measurement time. These analyses showed that the subscales of depression and anxiety of the HADS were positively associated at T0, T1 and T3. Descriptive statistics are summarized in Table 1.

A series of regression equations were subsequently designed with the MSS-14 (T0), for both patients and spouses/partners, and the MSS-MA-D and MSS-MA-AD scores as predictors of the variance in HAD-D and HAD-A at T0, T2 and T3. The partner's MSS-14 score was a negative predictor of patients depression at T0 ( $b = -0.152$ ,  $t = -2.467$ ,  $p = .028$ ) whereas the entire model was non-significant,  $F(2, 13) = 3.312$ , adjusted  $R^2 = .236$ ,  $p = .069$ . The MSS-MA-AD score predicted positively HAD-D at T0 ( $b = 3.083$ ,  $t = 2.613$ ,  $p = .023$ ), which underscores the impact of marital maladjustment on patients' mood. The model was non-significant,  $F(3, 12) = 2.478$ , adjusted  $R^2 = .228$ ,  $p = .111$ . Similarly, the MSS-MA-D score predicted positively HAD-D at T0 ( $b = 0.152$ ,  $t = 2.376$ ,  $p = .035$ ), suggesting that patients had more depressive symptoms when they strongly disagreed with their spouse/partner regarding marital adjustment and when they rated marital satisfaction

higher than their spouse/partner. The global model was nonetheless not significant,  $F(3, 12) = 2.073$ , adjusted  $R^2 = .177$ ,  $p = .157$ . Other analyses did not yield significant associations.

Next, we aimed at exploring the evolution of motor symptoms throughout the pre- and post-DBS procedure. As data of the MDS-UPDRS III were not normally distributed, we applied a linear (MDS-UPDRS III total score + 10) and a log 10 transformation. A repeated measures ANOVA including T0, T2, and T3 was subsequently designed. The main effect for MDS-UPDRS III yielded a ratio of  $F(2, 32) = 14.986$ ,  $p < .001$ ,  $\eta^2 = 0.178$ ,  $\omega^2 = 0.079$ , suggesting global improvement in motor symptoms.

As expected, planned contrasts revealed that the means of T0 and T2 were different,  $F(1, 16) = 23.103$ ,  $p < .001$ , and the means of T2 and T3 equal,  $F(1, 16) = 0.323$ ,  $p = .540$ . We used Bonferroni correction ( $\alpha/2$ ) to adjust  $p$ -values as contrasts were non-orthogonal. Further descriptive information is provided in Table 2.

Thereafter, we conducted a repeated measures ANOVA with the MSS-14 as dependent variable and including four measurement times (T0, T1, T2, and T3). This analysis was carried out with a subset of the sample ( $n = 9$ ) whose patients, at study inclusion, were aged  $63.67 \pm 5.83$  years old, had been in their current couple relationship for  $33.78 \pm 9.11$  years, and had  $1.56 \pm 0.73$  children. They had had a PD diagnosis for  $9.56 \pm 4.00$  years and were measured with a UPDRS-III (on medication) score of  $29.17 \pm 14.80$ .  $T$ -tests and chi-squared tests showed that these patients did not significantly differ at T0 from those not included in the longitudinal analyses on any of the socio-demographic variables and on marital satisfaction. However, they reported more severe motor disability at the UPDRS-III ( $t(28) = -2.778$ ,  $p = .010$ ). Because of sphericity violation (Greenhouse-Geisser  $\epsilon = 0.682$ ), we used Greenhouse-Geisser correction to interpret the analyses. The model showed a significant decreasing effect of couple satisfaction over time,  $F(2.047, 16.378) = 8.723$ ,  $p = .003$ ,  $\eta^2 = 0.164$ ,  $\omega^2 = 0.065$  (Fig. 1). Descriptive statistics for longitudinal analyses are displayed in Table 2.

Next, we decided to run post-hoc tests and further explore the dynamics of couple satisfaction. Summarized in Table 2, Tukey's HSD test between measurement sessions suggests that couple satisfaction remains stable from the pre-operative level to T1 but impairs at T2 and T3 (regarding both T0 and T1). This decreasing trend was not observed between T2 and T3, implying that dissatisfaction in the couple relationship stabilizes after 1-year post-operatively.

We then attempted to estimate growth trajectory of couple satisfaction over time using latent growth modeling with full information maximum likelihood estimation (FIML). We compared three nested models: the first one estimating a linear slope (model 1), the second one leaving the model

**Table 1** Univariate and bivariate descriptive statistics for variables of interest at every measurement session

Session	#	Variables	N	Mean	SD	Score range	Skewness	Excess kurtosis	1	2	3	4	5
T0	1	Couple satisfaction	25	58.880	9.297	37–70	-0.870 (0.464)	-0.119 (0.902)	1.000	-0.246	0.082	-0.317	0.597*
	2	Depression	30	5.367	3.388	0–13	0.744 (0.427)	0.084 (0.833)	1.000	1.000	0.385*	0.590*	0.445
	3	Anxiety	30	7.233	3.181	2–15	0.392 (0.427)	-0.293 (0.833)	1.000	1.000	1.000	0.330	0.092
	4	Marital adjustment (AD)	16	8.938†	9.781†	0–34†	-0.234 (0.564)	-1.508 (1.091)	1.000	1.000	1.000	1.000	0.428
	5	Marital adjustment (D)	16	3.313	13.006	-20 to 34	0.435 (0.564)	1.254 (1.091)	1.000	1.000	1.000	1.000	1.000
T1	1	Couple satisfaction	23	57.957	10.572	34–70	-0.881 (0.481)	-0.126 (0.935)	1.000	0.086	-0.026		
	2	Depression	24	4.625	2.481	1–10	0.322 (0.472)	-0.486 (0.912)	1.000	1.000	0.637*		
	3	Anxiety	24	6.417	2.827	2–14	0.870 (0.472)	1.381 (0.912)	1.000	1.000	1.000		
T2	1	Couple satisfaction	14	58.000	9.199	38–70	-0.703 (0.597)	0.427 (1.154)	1.000	-0.083	-0.149		
	2	Depression	17	4.294	2.995	1–10	0.374 (0.550)	-1.240 (1.063)	1.000	1.000	0.481		
	3	Anxiety	17	6.706	3.057	2–12	0.390 (0.550)	-0.848 (1.063)	1.000	1.000	1.000		
T3	1	Couple satisfaction	15	59.000	7.251	47–70	0.202 (0.580)	-1.077 (1.121)	1.000	-0.119	-0.162		
	2	Depression	18	5.500	3.148	1–12	0.382 (0.536)	-0.252 (1.038)	1.000	1.000	0.671*		
	3	Anxiety	18	7.611	3.632	2–14	0.163 (0.536)	-1.161 (1.038)	1.000	1.000	1.000		

Marital adjustment computed with score absolute differences (AD) and differences (D). Standard errors for skewness and excess kurtosis are displayed in brackets. Columns 1–5: bivariate Pearson's correlations between variables for each measurement session

Couple satisfaction = MSS-14, Depression = HAD-D, Anxiety = HAD-A

\*p Value significant at the .05 threshold

†Non-transformed values are displayed in the table for readability reasons

**Table 2** Univariate and bivariate descriptive statistics for variables of interest

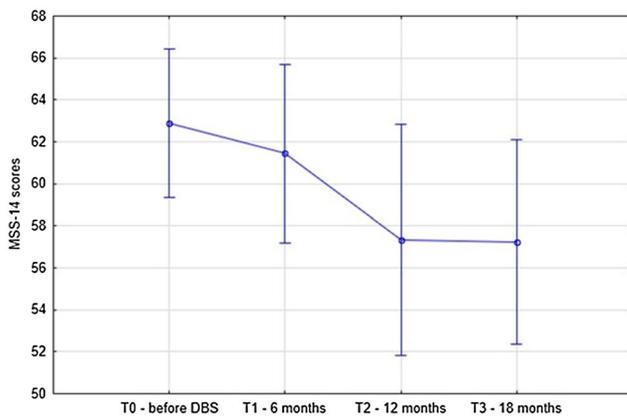
#	Variables	Session	N	Mean	SD	Score range	Skewness	Excess kurtosis	T0	T1	T2	T3
1	Motor symptoms	T0	17	23.941†	12.191†	8–59†	0.373 (0.550)	0.802 (1.063)	N/A	N/A	<0.001*	N/C
		T2	17	14.441†	7.399†	2–29†	–0.461 (0.550)	–0.081 (1.063)	N/A	N/A		0.540
		T3	17	15.294†	7.465†	4–28†	–0.068 (0.550)	–0.812 (1.063)	N/A			N/A
2	Marital satisfaction	T0	9	62.889	4.595	53–68	–1.310 (0.717)	1.867 (1.400)	N/A	0.725	0.003*	0.002*
		T1	9	61.444	5.525	51–69	–0.587 (0.717)	0.259 (1.400)		N/A	0.031*	0.026*
		T2	9	57.333	7.176	44–69	–0.089 (0.717)	1.086 (1.400)			N/A	0.998
		T3	9	57.222	6.320	47–66	0.053 (0.717)	–0.454 (1.400)				N/A

Standard errors for skewness and excess kurtosis are displayed in brackets. Columns T0-T3 correspond to *p*-values for planned contrasts (Motor symptoms), respectively Tukey’s HSD post-hoc comparisons (Couple satisfaction)

N/A not applicable, N/C not computed

\**p*-value significant at the .05 threshold

†Non-transformed values are displayed in the table for readability reasons



**Fig. 1** Means with 95% confidence intervals for MSS-14 scores at T0, T1, T2 and T3 (*n* = 9)

estimate the slope (model 2), and the last one estimating a linear and a quadratic slope (model 3). Although all models globally showed adequate fit to the data, model 2 had the best indices as shown in Table 3. Notably, chi-squared improvement in model 3 compared to model 2, obtained with a loss of two degrees of freedom, was not significant ( $\Delta\chi^2 = 0.384$ ,  $\Delta df = 2$ , *p*-value = .825). Regression weights for slope in the prediction of MSS were *b* = 0.071, *p* = .093 at T1 and *b* = 2.938, *p* < .001 at T2.

We additionally performed Bayesian estimation for each model as this procedure has been considered adapted to

analyses of small sample sizes (Spiegelhalter, Abrams, & Myles, 2004). Analyses performed with Bayesian estimation confirmed that model 2 was the most adapted, with convergence statistic < 1.002, stable trace plots, and comparison of first and last third of each parameter’s posterior distribution showing convergence. However, slightly unstable autocorrelation plots and discrepancies in value estimates for variances suggested that Bayesian and FIML solutions were not totally identical.

### Discussion

Among the few studies addressing the issue of couple relationship in relation to DBS for PD, this one is to our knowledge the first to provide longitudinal, quantitative data including pre- and post-surgical measures. This study primarily considers the patient’s perspective in post-DBS satisfaction in the couple relationship as spouses/partners were not included in longitudinal analyses. Conducted on a small sample, it remains exploratory and its findings will have to be replicated before definitive conclusions can be drawn. Bearing these limitations in mind, we have conducted analyses resulting in the following considerations.

We found that couple satisfaction, as perceived from the patient perspective, lowered after DBS despite concomitant motor improvement. Couple satisfaction was nevertheless not associated with anxiety or depression, either at

**Table 3** Comparisons of latent growth curve models estimating growth trajectory for couple satisfaction over a 18-month follow-up (T0–T3)

#	Tested models	$\chi^2$	df	<i>p</i> Value	$\chi^2/df$	CFI	SRMR	RMSEA (90% CI)	Model comparison	$\Delta\chi^2$	$\Delta df$	<i>p</i> Value
1	Linear	10.344	8	.242	1.293	0.917	0.051	0.191 (0.000–0.482)	1 vs. 2	5.860	2	.053
2	Slope estimates	4.484	6	.611	0.747	1.000	0.044	0.000 (0.000–0.388)	1 vs. 3	6.244	4	.182
3	Linear and quadratic	4.100	4	.393	1.025	0.996	0.036	0.056 (0.000–0.539)	2 vs. 3	0.384	2	.825

the highly symptomatic stage of the immediate pre-DBS period or at any time within the 18 months following surgery. However, problems of marital adjustment—expressed by disagreements between the patient and the spouse/partner regarding their perception of couple satisfaction—predicted higher levels of depression in patients at the pre-operative period. This was notably the case when marital maladjustment was characterized by the patient being more satisfied than his/her spouse/partner.

Counterintuitive at first glance, post-operative impairment of couple satisfaction may be understood in the line of studies showing that DBS for PD is sometimes followed by psychosocial maladjustment (Bell, Maxwell, McAndrews, Sadikot, & Racine, 2011; Flores Alves Dos Santos et al., 2017; Gilbert, 2012). In this context, problems in the couple relationship have been associated with the process of struggling to reach optimal adjustment of stimulation parameters (Haahr et al., 2013; Perozzo et al., 2001), differences in the perception of the DBS benefits and potential associated role changes (Bell et al., 2011; Haahr et al., 2010; Perozzo et al., 2001), or emotional issues in the dyad (Agid et al., 2006; Schüpbach et al., 2006). Some of these difficulties occurred during the few months following surgery (Haahr et al., 2010, 2013; Perozzo et al., 2001), and our data show that couple satisfaction especially lowered between 6 and 12 months as demonstrated by growth curve analyses. These findings support the work of Haahr et al. (2010), who described an adjustment period of about 12 months taking place after surgery in which patients must adapt to the new demands of a less symptomatic life. The corollary of this is that the adjustment process seems to come to an end after 1 year. We indeed observed a stabilization of couple satisfaction scores at this measurement time (i.e., T2) but no improvement nor even a trend toward a return to pre-operative values. In this regard, our data align with previous work showing that couple difficulties are still current 2 years post-operatively (Agid et al., 2006; Schüpbach et al., 2006).

The fact that couple satisfaction was never associated with depression or anxiety may be interpreted in two ways. First, post-operative deterioration did not reach critical levels; indeed, the lowest average MSS-14 score (57.2 at T3) remained above the threshold of 53 proposed to discriminate distressed from non-distressed relationships (Baertschi et al., 2017). Second, the variable of couple relationship is not sufficient to be representative of the affective experience of PD patients undergoing DBS, as the latter depends on multiple causes. In this regard, a measure of marital adjustment may be more sensitive to predict variance in emotional variables, as illustrated by our findings at the pre-operative period. Further research is nevertheless warranted to continue investigating this field.

This study has limitations that should be considered in the interpretation of its findings. First, the small sample

size attenuated statistical power, which might have fostered occurrence of type II errors (e.g., the absence of expected significant correlation between depression and anxiety at T1) and might account for the small effect sizes reported in both repeated measures ANOVAs. Similarly, the small sample size might account for the partial differences in model estimations between FIML and Bayesian solutions. Second, our study design allowed us to assess couple satisfaction mainly from the patient perspective. Measures of marital adjustment including spouses/partners were available but only at T0, which has strongly limited the longitudinal interpretation of our analyses. Finally, we did not have a measure of MDS-UPDRS III at T1. While neurological routine evaluations indicated that patients already benefitted from DBS 6 months after DBS, we were not able to attest for it quantitatively. Thus, although extremely unlikely, we could not rule out the possibility that MSS-14 scores at T1 were measured in a context of sustained motor problems.

Despite these limitations, this study contributes to understand the dynamics of couple relationship throughout the DBS experience in PD. It supports previous conclusions suggesting that post-operative psychosocial adjustment does not entirely depend on motor symptoms. Replication is yet necessary to confirm these results, notably with regard to the small sample size and the limited incorporation of data pertaining to spouses/partners. Our results nevertheless open perspectives for health professionals of various clinical disciplines, such as nurses, psychiatrists, and psychologists doing family and consultation-liaison interventions.

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## Compliance with Ethical Standards

**Conflict of interest** The authors Marc Baertschi, Nicolas Favez, João Flores Alves Dos Santos, Michalina Radomska, François Herrmann, Pierre Burkhard, Alessandra Canuto, and Kerstin Weber declare that they have no conflict of interest.

**Human and Animal Rights** All procedures were in accordance with the ethical standards of the institutional research committees and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

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