Diagnostics of olfactory dysfunction in Parkinson's disease – a literature overview and case series

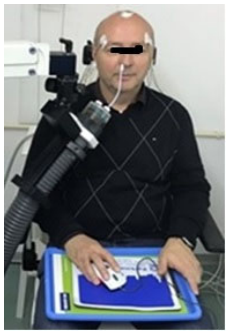
Libor Vasina[1,2#], Nikola Pastorkova[3], Oleksii Vorobiov[2,4], Karla Janouskova[2,4], Petra Dytrych[5,6], Jiri Hlozek[2,4], Sarka Musilova[3], Jaromir Astl[2,4], Richard Holy[2,4#]

Olfactory dysfunction is increasingly recognised for its predictive value as an early indicator of a number of degenerative neuropathologies including Parkinson's Disease (PD). In this overview, we cover the relationship between PD and olfactory dysfunction (OD). Prodromal premotor symptoms of PD include sleep disturbances, psychiatric disorders, constipation and OD. The latter can precede motor symptoms by several years and its occurrence is frequent in Parkinson s disease with a prevalence that can range from 45%–90%. Olfactory perception in these cases can be tested using subjective and objective methods. Commonly used psychophysical tests in the Czech Republic include Sniffin' Sticks Tests and the Odorized Marker Test but these may be inaccurate and demanding on patients with cognitive deficits in addition to motor symptoms. For these reasons, objective electrophysiological olfactory tests that depend on olfactory/trigeminal event-related potentials (OERPs/TERPs) for example are more useful. In this paper we describe a series of case reports, demonstrating the importance of comprehensive olfactory examination. The significance of objective electrophysiological olfactory/ trigeminal tests in the diagnosis of PD, is underscored given the rising incidence of this condition and the need for early diagnosis.

DIAGNOSTICS OF OLFACTORY DYSFUNCTION IN PARKINSON'S DISEASE

Olfactory dysfunction should therefore be considered a reliable marker of the **Parkinson's disease.** Olfactory perception in Parkinson's disease can be tested by **psychophysical and objective methods.** Psychophysical smell tests can be burdened by inaccuracy and poorer cooperation of subjects with Parkinson's disease.

Objective electrophysiological olfactory tests include olfactory/ trigeminal event-related potentials (OERPs/TERPs). These objective tests may be suitable for olfactory testing in subjects with Parkinson's disease, who, in addition to motor symptoms of the disease, may also have a cognitive deficit.



In the review and case series, we demonstrate the importance of comprehensive olfactory examination in Parkinson's disease.

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Graphical Abstract
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[1]*Department of Neurology, Military Hospital Brno, Brno, Czech Republic*
[2]*Third Faculty of Medicine, Charles University, Prague, Czech Republic*
[3]*Department of Neurology, Military University Hospital Prague, Prague, Czech Republic*
[4]*Department of Otorhinolaryngology and Maxillofacial Surgery, Third Faculty of Medicine, Charles University and Military University Hospital Prague, Prague, Czech Republic*
[5]*Department of Ear, Nose and Throat, University Hospital Motol, Prague, Czech Republic*
[6]*Second Faculty of Medicine, Charles University, Prague, Czech Republic*
[#]*These authors contributed equally to this research*
Corresponding author: Libor Vasina, e-mail: LVasina@vnbrno.cz

INTRODUCTION

In this overview, we cover the relationship between PD and olfactory dysfunction (OD). Parkinson's disease (PD) is a neurodegenerative disorder manifested by resting tremor, rigidity, bradykinesia, and postural instability[1,2]. This motor phase of the disease is preceded by a premotor prodromal phase. Symptoms of this phase include psychiatric and cognitive disorders, rapid eye movement (REM) sleep disorder, dysautonomia, and olfactory dysfunction (OD) (ref.[2,3]). OD can appear several years before the diagnosis of PD is established[4]. OD affects the quality of life of patients[5], as the sense of smell has a fundamental influence on the taste of food and the identification of harmful volatile compounds. PD is the second most common neurodegenerative disease in the world after Alzheimer's dementia. It is estimated that there are more than 10 million people with PD worldwide[6]. The incidence of PD is 10–50 cases per 100,000 inhabitants per year. The prevalence rate is 100–300 patients per 100,000 inhabitants per year, PD has a higher prevalence in men. It typically occurs between the ages of 65 and 70. There are known cases (5%) where PD appears in subjects younger than 40 years[7,8]. From a quantitative perspective, severe hyposmia to anosmia is relatively often found in PD (ref.[9]). The abilities of the sense of smell include detection (sensitivity to the lowest concentration of a substance – threshold), discrimination (distinguishing odors at suprathreshold concentrations), and identification (naming the source of an odor)[10].

Olfaction can be tested by psychophysical and objective neurophysiological methods[11,12]. Psychophysical tests – the Sniffin' Sticks Identification Test (SSIT) (ref.[11,13]), frequently used in our region. Worldwide, the University of Pennsylvania Smell Identification Test (UPSIT)[14] is widely used, which is based on the "scratch and sniff" technology[15]. Its reduced version is the Brief Smell Identification Test (B-SIT) (ref.[16]). A commonly used screening psychophysical test in the Czech Republic is the Odorized Marker Test (OMT) (ref.[17,18]), invented by researchers in Pardubice[19]. Objective neurophysiological methods of olfactory examination include the evaluation of olfactory event-related potentials (OERPs) and trigeminal event-related potentials (TERPs) (ref.[11,20]). The advantage of the objective method is that OERPs are less distorted than routinely used psychophysical olfactory tests[21]. A clinical olfactometer provides precisely defined olfactory stimuli necessary to elicit OERPs and TERPs (ref.[22]). The principle of the method is based on the presentation of an odorant through a special device in the patient's nasal cavity and the registration of the brain's response to olfactory and trigeminal stimuli using electroencephalography (EEG) (ref.[21]). In OERPs and TERPs, we evaluate the latencies and amplitudes of individual peaks and the N1–P2 interval[9,23]. The absence of OERPs is a strong predictor of the presence of OD (ref.[20,22]). In practice, the clinical olfactometer OL 024 Burghart and the eight-channel EEG system OL 026 Burghart are most commonly used. Objective electrophysiological methods have increasing potential, especially in individuals who have difficulty with commonly available psychophysical olfactory testing, such as individuals with neurodegenerative diseases[9,20]. A common finding in PD is the absence or abnormality of OERPs (ref.[24]). Some studies describe that, in terms of trigeminal nerve perception, the olfactory dysfunction in Parkinson's disease is different from other olfactory disorders. The sensitivity of the trigeminal nerve is not impaired in patients with PD (ref.[25]).

It is necessary to mention objective imaging methods such as magnetic resonance imaging (MRI) of the olfactory bulb and olfactory sulcus. This method finds application in patients with epilepsy, schizophrenia, Parkinson's disease, Alzheimer's disease[26].

Another objective imaging modality cannot be overlooked, that is functional magnetic resonance imaging (fMRI). The use of fMRI has advanced our understanding of OD specifically in PD patients[27,28].

SERIES OF CASE REPORTS

We refer to a series of three case reports. All three subjects had confirmed PD and OD.

A comprehensive olfactory examination was performed on the examined subjects using both subjective and objective electrophysiological olfactory tests. All subjects underwent MRI of the brain.

Case Report 1

A 77-year-old male, diagnosed with PD since 2007. The first symptom was tremor. He has noticed olfactory dysfunction since 2020. Psychophysical smell tests were performed. OMT resultes: 6+2=8 points (hyposmia). SSIT: 13 incorrect answers / 3 correct answers (anosmia). Subsequently, electrophysiological olfactory tests OERPs/TERPs were performed. OERPs curves were absent. TERPs curves were present. Wave N1 (latency / amplitude): 264 milliseconds (ms) / −4 microvolts (uV). Wave P2 (latency/amplitude): 381 ms / 7 uV. (see Fig. 1 and 2). Brain MRI was performed with the conclusion: cerebral atrophy, advanced glial changes.

Psychophysical smell tests demonstrate OD, objective tests show the absence of OERPs, and the presence of TERPs.

Case Report 2

A 64-year-old male, diagnosed with PD since 11/2023. The first symptom was tremor. He has noticed olfactory dysfunction since 2021, two years before being diagnosed with PD.

Psychophysical smell tests were performed. OMT results: 5+1=6 points (hyposmia). SSIT: 7 incorrect answers/ 9 correct answers (hyposmia). Subsequently, electrophysiological olfactory tests OERPs/TERPs were performed. OERPs curves were absent, TERPs curves were absent (see Fig. 3 and 4). Brain MRI was performed with the conclusion: glial changes in white matter.

Psychophysical smell tests demonstrate OD, objective tests show the absence of both OERPs and TERPs.

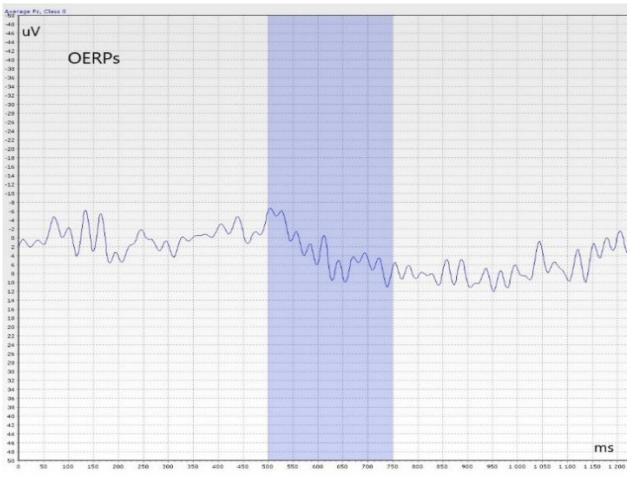

Fig. 1. Absence of OERPs curves in Parkinson's disease (Case report 1) (from the archive of co-author MUDr. Holý).

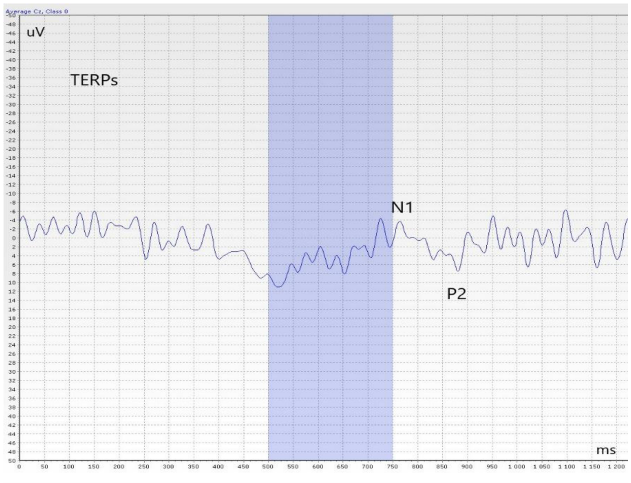

Fig. 2. Presence of TERPs curves in Parkinson's disease (Case report 1) (from the archive of co-author MUDr. Holý).

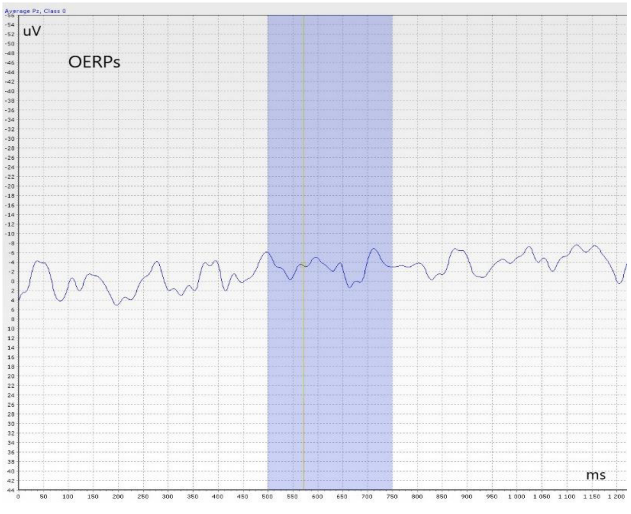

Fig. 3. Absence of OERPs curves in Parkinson's disease (Case report 2) (from the archive of co-author MUDr. Holý).

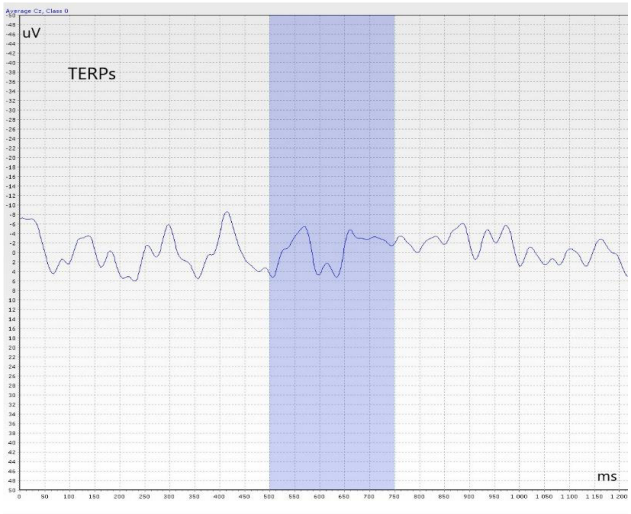

Fig. 4. Absence of TERPs curves in Parkinson's disease (Case report 2) (from the archive of co-author MUDr. Holý).

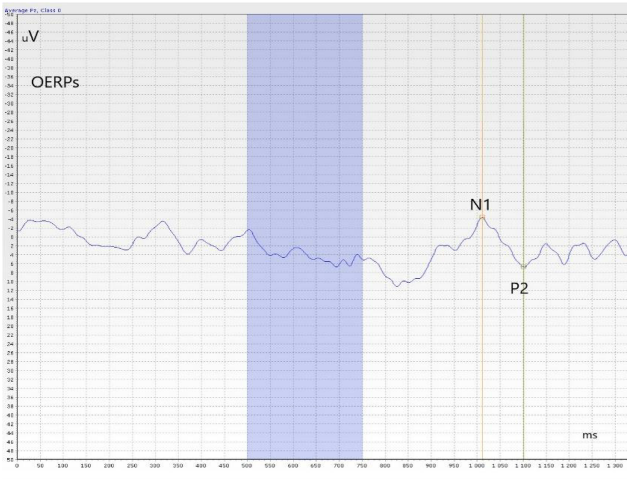

Fig. 5. Presence of OERPs curves in Parkinson's disease (Case report 3) (from the archive of co-author MUDr. Holý).

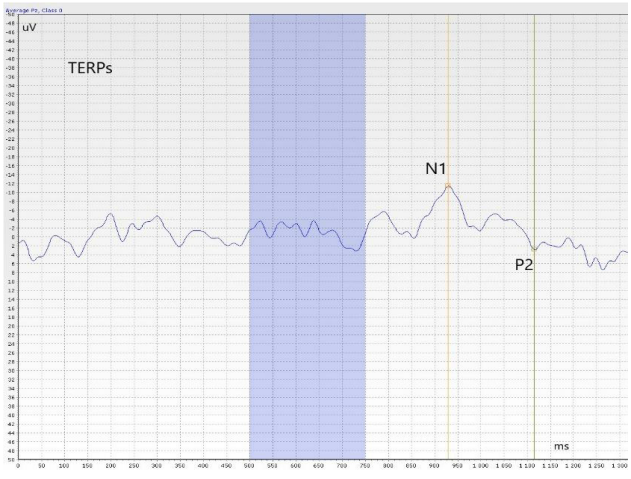

Fig. 6. Presence of TERPs curves in Parkinson's disease (Case report 3) (from the archive of co-author MUDr. Holý).

Case Report 3

A 64-year-old male, diagnosed with PD since 3/2023. The first symptoms were tremor and limb stiffness. He has noticed OD since 1993. Psychophysical smell tests were performed. OMT results: 6+3=9 points (normosmia). SSIT: 13 incorrect answers / 3 correct answers (anosmia). Subsequently, electrophysiological olfactory tests OERPs/TERPs were performed. OERPs curves were present. TERPs curves were present (see Fig. 5 and 6).

OERPs (latency/amplitude): Wave N1 511 ms / −4 uV. Wave P2: 601 ms / 7 uV.

TERPs (latency/amplitude): Wave N1 399 ms / −2 uV. Wave P2: 588 ms / 11 uV.

Brain MRI was performed with the conclusion: multiple foci of glial changes, ventriculomegaly.

Psychophysical smell tests demonstrate OD, objective tests show the presence of both OERPs and TERPs.

DISCUSSION

The occurrence of OD in PD is frequent. Current data on the prevalence of OD in Parkinson's disease range between 45% and 90%. OD should therefore be considered a reliable marker of the disease[29]. Approximately 68% of patients with PD are unaware of OD (ref.[30]). Therefore, a comprehensive understanding of OD in subjects with PD is essential for improving early diagnosis and therapy[31]. A decline in olfactory function precedes classic motor symptoms of PD by years and thus serves as a preclinical or premotor biomarker of PD (ref.[32-34]). In a study involving over 2000 men, the B-SIT test found that impaired identification occurs at least four years before motor symptoms of PD (ref.[34]). Similar results were obtained using the SSIT (ref.[32]). OD was also found in familial parkinsonism[35] and in first-degree relatives of patients with sporadic PD who do not exhibit motor symptoms of the disease. Patients are unaware of the deterioration of their sense of smell[36]. In our three examined subjects, OD appeared in a range of 20 years before the diagnosis of PD to 13 years after the diagnosis of PD.

Factors affecting olfactory test scores include gender and age[7,8]. In accordance with literary data, our three subjects were all males aged 64–77 years. In our smell lab, we investigated a subject with PD aged 47. Antiparkinsonian therapy does not affect olfactory function[37-40]. Milder OD accompanies progressive supranuclear palsy, multiple system atrophy, and essential tremor. In the UPSIT test, patients with progressive supranuclear palsy did not show a significant difference compared to healthy individuals[41-43]. Multiple system atrophy is accompanied by a mild decline in olfactory function[41,44-47]. Unlike quantitative olfactory disorders, the occurrence of dysosmia in PD is not common. The study by Landis and Burkhart describes the development of PD simultaneously with the disappearance of phantosmia in two patients who did not show severe quantitative olfactory disorders. They believe that phantosmia could be a premotor symptom of PD (ref.[48]). Another study found that none of the 44 patients with idiopathic phantosmia developed PD during 10 years of follow-up. According to the authors, phantosmia is therefore a rather insignificant symptom than an early biomarker of PD (ref.[49]). Another study reports the occurrence of olfactory hallucinations in 10% of 87 patients with PD, but in none of the control subjects[50]. In our case report series, we did not record olfactory hallucinations or parosmia.

Hummel et al. found that stimuli presented using a clinical olfactometer were rated as less intense but more pleasant by patients compared to the control group[51]. The difference in the evaluation of perceptual characteristics of stimuli between patients with PD and the control group may depend on the nature of the presented stimuli and their ability to irritate the trigeminal nerve. In patients with PD, the decline across olfactory abilities is more homogeneous[51].

It has been reported that compared to Alzheimer's dementia, detection thresholds are increased, meaning olfactory sensitivity is reduced[52]. One of the reasons could be reduced activity of odorant inhalation[37]. However, the decline in olfactory function cannot be explained by this deficit, as objective instrumental olfactometry does not require the cooperation of examined subjects. Namely, the examined person does not actively inhale the stimuli, the air with the odorant is instrumentally guided to the nasal mucosa[53].

In 2010, Vodička et al. in the Czech Republic successfully attempted to demonstrate the application of psychophysical smell tests OMT and SSIT used in our region in the detection of OD in PD (ref.[18]). In our case report series, we demonstrated OD using psychophysical tests in all three referred subjects. German authors report 96% hyposmia/anosmia detected by SSIT in their big group of subjects with PD (ref.[29]). For OMT, achieved values were 6 to 9 points. Vodička et al. report a median value of 6 points (range 2–8) in PD. For SSIT, we detected 3 to 9 points, Vodička et al. report a median of 8 points (range 4–11) (ref.[18]). Researchers from Dresden also report a median SSIT result of 8 points[54] and the detection of 96% hyposmia/anosmia using SSIT in subjects with PD (ref.[28,54]). British researchers Hawkes et al. reported in their study the occurrence of OD in more than 70% of subjects with PD. They tested smell using psychophysical tests[24]. In our smell lab, according to preliminary measurements, we recorded anosmia in 70% of cases and hyposmia in 27%. We have identified OD in more than 97% of subjects with PD so far.

It is reported that in PD, quantitative impairment of olfactory abilities (detection, discrimination, identification), as cognitive abilities[55], reflects a progressive deficit in executive functions and semantic memory[56-58].

Some studies report that the results of psychophysical tests in cognitive disorders can be significantly distorted. Therefore, it is more advantageous to use methods less dependent on cognitive functions, namely objective electrophysiological olfactory tests OERPs/TERPs. Interestingly, if a healthy subject undergoing an olfactory examination shows worse results than expected in the age group of the healthy population, they have an increased relative risk of developing PD. Examination of olfactory function can help in establishing a diagnosis. It can help reveal changes

in function in brain areas co-responsible for processing olfactory information[59,60].

We know from the literature that OERPs are typically severely delayed or even absent in subjects with PD. However, there are not many studies in the literature that deal with electrophysiological olfactory tests in PD. Hawkes et al. report abnormal OERP recordings in 49% of subjects with PD in their study[24]. Welge-Lüssen et al. reported a 50% absence of OERPs in 18 subjects[27]. Preliminary data from our smell laboratory detects the absence of OERPs in 51% of subjects with PD.

Several studies have reported the presence of OD in PD in association with the absence of OERPs.

On the other hand, trigeminal nerve function in Parkinson's disease is very rarely reported in the literature. Intact trigeminal sensitivity is described in subjects with PD. Tremblay et al. in a Canadian-German studies reported that on electrophysiological olfactory measurements, subjects with Parkinson's disease showed similar trigeminal sensitivity to healthy control subjects[25,61]. A similar experience was reported by German authors in their study[53]. This fact could distinguish OD in PD subjects from other OD in the future[25,61]. In our laboratory, preliminary analyses suggest that we observed the absence of OERPs in the simultaneous presence of TERPs in 16% of subjects with PD examined by electrophysiological olfactory methods.

In our case report series, the findings of OERPs and TERPs were interesting. In two cases, we detected the absence of OERPs, and in one case, OERPs were present, but compared to pilot data in healthy subjects[20], the N1 and P2 curves were prolonged by more than 100 miliseconds. The findings of TERPs were also interesting. TERPs were absent once when OERPs were absent. In two case reports, TERPs were present, once when OERPs were absent and once when OERPs were present. The latencies of TERPs did not significantly differ from pilot data of healthy subjects[20]. By examining olfaction along with other methods, we can monitor disease progression[62].

The importance of objective imaging methods in the diagnosis of OD in subjects with PD has been reported in the literature. In brain MRI, the examination is focused on the olfactory bulbus and olfactory sulcus. For the olfactory bulb, we are interested in its volume. It has been described in the literature that its volume varies in neurodegenerative diseases, for example. Rombaux et al. in their study did not observe olfactory bulb volume differences in subjects with PD (ref.[63]). Recently, some studies have addressed the importance of brain fMRI in PD. Hummel et al. report in detail how olfactory stimuli applied during fMRI scans can show modulation of central nervous system structures related to PD. This is an important factor for our detailed understanding of OD in PD patients[26].

Some older studies have already presented the hypothesis that OD precedes motor symptoms in subjects with PD. A study that provided more significant evidence in this regard was conducted by Ross et al. They studied olfactory function in 2267 men without clinical symptoms of PD for eight years. During this period, 35 cases of Parkinson's disease were diagnosed. It was found that those who scored lower on the subjective olfactory examination using SSIT had a higher risk of developing PD in the following four years[4]. Subsequently, other prospective studies were conducted to clarify the role of OD in the prodromal stage of PD. Haehner et al. followed a group of 30 patients with idiopathic hyposmia. After four years, PD developed in 7% of people, so the authors concluded that hyposmia could be the first symptom of PD (ref.[32]). Then, in 2018, Haehner et al. followed 474 patients with idiopathic loss of smell, with an average of 11 years later, 45 of them (9.8%) developed PD (ref.[29]). Given the above, OD could be an early biomarker of PD and therefore could be a valuable indicator in the early diagnosis of PD (ref.[64]).

CONCLUSION

In this overview, we report that olfactory dysfunction is a common and early symptom of PD. The literature suggests the use of olfactory testing as a biomarker for the early diagnosis of PD and further in the assessment of its progression. Objectified OD may be an important indicator in identifying the prodromal phase of PD. OD is now recognized as a supportive diagnostic criterion for early screening of PD. For accurate measurement of OD in subjects with PD, it is advisable to use a comprehensive olfactory examination that includes not only standard psychophysical olfactory tests but also electrophysiological examination of not only the sense of smell but also trigeminal function. It is certainly advisable to also indicate brain MRI with a focus on the olfactory bulb. In the future, brain fMRI technology will also be developed for the diagnosis of PD. Recently, the importance of OERP/TERP in the diagnosis of PD has been growing. The absence of OERPs is a strong predictor of the presence of OD. The presence of TERPs could help in the detailed differentiation of olfactory dysfunction in PD from other OD. In the future, detailed research on OD in PD can be expected, using comprehensive olfactory testing with a special focus on OERPs/TERPs.

Search strategy and selection criteria

Our search strategy aimed to evaluate current studies and reviews published olfactory dysfunction in Parkinson's disease. Scientific articles were searched using the PubMed and Web of Science and Medvik databases. All searches were up to June 2025. The search terms included "smell", "olfactory dysfunction", "Parkinson's disease", "OERPs", "TERPs". Only the full texts of the articles in English were reviewed.

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administration; LV, RH, JA: funding acquisition. All authors have read and agreed to the published version of the manuscript.

Conflict of interest statement: The authors state that there are no conflicts of interest regarding the publication of this article.

Ethic approval: Our study was approved by the Ethics Committee of the Military University Hospital Prague – Reference Number 108/16-24/2021.

Informed consent statement: The patients presented in this manuscript signed an informed consent for the olfactory examination.

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