Supplementary Material

Oral Health Disorders in Parkinson's Disease: More than Meets the Eye

Supplementary Table 1: Summary of the main findings found in international literature regarding oral cavity disorders in patients with Parkinson's disease (orofacial symptoms, oral and dental health, oral hygiene)

Reference / Country	Subjects (PD patients ± controls) & type of assessments	Main findings
Anastassiadou et al., 2002 [1] /Greece	• N= 51 (32 males), 40-83 y; all PD stages represented in the sample; • No control group • Objective & subjective assessments	• Orofacial symptoms: **hypomimia** (80%), **monotonous speech** (62%), **facial muscles rigidity** (78%), **tremor** (47%) • Oral disorders: **xerostomia** (67%), **drooling** (22 and 24% (?)), **chewing** problems (39%), **swallowing difficulties** (29%), **nausea** (14%) • Dental disorders: **tooth erosion, periodontal disease**, coronal and root **caries**; dentures wearer (98%) but **poorly fitting dentures**, causing ulcers, hyperplasia & inflammation • Oral hygiene: **difficulties in performing oral hygiene** (57%), up to the inability to brush teeth/dentures without help (12%) • **Food preferences**: "softer food, fish rather than meat, fresh vegetables well cooked and soft or melted fruits" • No association between age and dental status nor between dental status and PD duration in the cohort (authors' hypotheses: early diagnosis, good medication control and/or family support ?)
Bakke et al., 2011 [2] /Denmark	• N= 15 (6 males), 61–82 y; mean PD duration 6.7 ± 3.8 y, **Hoehn & Yahr stages 2–4** • Compared to age- and gender-matched control subjects • Objective & subjective assessments	• **Poorer orofacial function & oral health** compared to controls ➢ Impaired **masticatory function**: reduced masticatory ability & performance, reduced maximum jaw opening capacity ➢ Frequent **drooling** of saliva • **Increased impairment with disease severity**
Barbe et al., 2017 [3] /Germany	• N= 100 (72 males), mean age 71 ± 8.7 y, mean PD duration 9.5 ± 6.4 y • No control group • Subjective assessments	• Oral disorders: **xerostomia** (49%), **drooling** (70%), slight to moderate **dysphagia** (47%), • Oral hygiene: 100% **≥ 1 toothbrushing /day** but **limited ability to perform oral hygiene** (29%). 38% used **additional mouth wash**. **No use of dental floss** nor any devices developed for the elderly • Follow-up: 91.8% had their own dentist, with **≥ 1 visit/y for 87.8%**. **Lack of dental advice**: only 6.1% of patients with xerostomia received advice regarding management • Nutritional intake: **snack(s)** consumed between meals (98.9%), increased fluid intake (97%) • Oral health-related symptoms (xerostomia, drooling, and dysphagia) negatively **impaired oral health-related quality of life** (the longer the PD duration, the higher the negative impact)

Barbe et al., 2017 [4] /Germany	• N= 26 (14 males), mean age 69 ± 9 y, mean PD duration 9 ± 4 y, mean LEDD 680 ± 385 mg/day (85% were on dopaminergic agonists) • Compared to age- and gender-matched control subjects • Objective & subjective assessments	• **High prevalence of periodontitis** (68%), higher plaque and gingival indexes • Impaired organoleptic sense in 58% of PD patients (vs 4% of controls) • Halitosis: more PD patients **subjectively reported bad breath** (77%) and **perceived their bad breath to be stronger** -even though the organoleptic score (objective assessment) was the same. Being told they had bad breath was more common in PD patients than in controls • **Lower saliva** volumes in PD patients and **higher xerostomia scores** (no correlation with prevalence or intensity of halitosis) • **Impaired oral health-related quality of life**
Cicciù et al., 2012 [5] /Italy	• N=45 (17 males), 65-78 y, **Hoehn & Yahr stages 1-2**, recruited in the Neurology department • Compared to 45 (35 males), control subjects, recruited at the Odontostomatology department, "where they came for routine dental visits". "Comparable & similar" mean age between the groups • Objective assessments & interview	• **Poorer oral health** compared to controls • **Higher frequency of periodontal disease**, with more a deeper periodontal pockets & severe tooth mobility, in the PD group • **More missing teeth** in the PD group • No significant difference between the percentages of untreated caries teeth on both group • Patients' request & problems about dental hygiene: **discomfort with mouthwashes** (authors' hypothesis: maybe for the fear of choking)
Clifford & Finnerty, 1995 [6] /United Kingdom (England & Northern Ireland)	• N= 228 -with missing data (121 males), median age 69.5 y; members of a PD society • Subjective assessments (self-reporting, postal questionnaire) • No control group	• Dental attendance & follow-up: **48% had attended a dentist within the last year**; 60% within the last two years (with **discrepancies according to location** -difficulties in obtaining convenient appointment/finding a likable dentist, long way to travel). Reasons for attending: 47% trouble with teeth & gums, 30% routine examination, 18% denture problems. • Common dental complaints: **xerostomia** (55.1%), **dysphagia** (48.0%), **loose dentures** (31.3%), **poor denture control** (27.8%), **sore gums** (22.5%), **ulcers** (17.2%), **bleeding gums** (11.5%), **burning sensation** (9.7%), **loose teeth** (8.4%), **sore teeth** (5.3%). 51% reported a dental problem within the last year (49% teeth-related, 30% denture-related). • **Perceived value of dental care: 71% extremely or very important; 86% felt mostly or completely satisfied** with the care received *("only 13% felt that a dentist would have trouble treating them and of these 30% cited muscle related problems such as spasms and tremors as the reason")*. **38% felt they were in need of some form of treatment** • **Barriers to dental care: anxiety/fear (59%), cost (50%), access (30%)**
Einarsdóttir et al., 2009 [7] /Iceland	• N= 67 • Compared to 55 control subjects (PD patients' spouse or family member)	• More **missing teeth:** *"it could be speculated that patients, and even dentists, were **unwilling to embark on complex restorative treatment of carious teeth** and chose instead to **extract** teeth that in healthier subjects would have been restored. **Treatment costs** may well have been a consideration in this decision"*

	• Objective & subjective assessments	• Poorer oral hygiene, with more **dental plaque** (64%), and **caries**, **despite no differences in toothbrushing and dental visits frequency, and higher use of dental floss** (compared to controls) • **Poorer periodontal health**, with **gingivitis** (60%) & greater mean pocket depth (4.15) • **Higher counts of cariogenic bacteria** in saliva (*Streptococcus mutans* & lactobacilli) with a trend towards higher sugar/sweets consumption but no statistical significance • Comparable flow rates of stimulated whole saliva
Frota et al., 2016 [8] /Brazil	• N= 35, institutionalized, mean age 71.3 (57-87) y, • Other groups: controls (N=20, mean age 68.8 y), patients with Alzheimer's disease (N=35, mean age 74.2 y) • Objective assessments	• **No differences** in the occurrence of oral diseases between the groups • PD group characteristics: ➢ Periodontal disease (31.4%), 5.7% of residual roots, 22.8% of caries; 11.4% abscess ➢ 5,7% angular cheilitis; 2.8% bruxism ➢ **42,8% totally edentulous**, 25.7% of total dentures & 34.2% of removable partial dentures; ➢ Removable dental prosthesis (N=21): **85.7% unsatisfactory state**, 85.7% unsatisfactory retention, 71.4% of unsatisfactory occlusion, 90.4% presence of defects, 66.6% associated oral pathology
Fukayo et al., 2003 [9] /Japan	• N= 31 (17 males), aged ≥ 60 y, **Hoehn & Yahr stages 1–3** • Compared to 104 control subjects (61 males), aged ≥ 60 y • Objective & subjective assessments	• **Better dental status** (lower DMFT score -Decayed, Missing and Filled Teeth) in PD patients: *"since the present study only deals with patients with mild symptoms, it should be noted that the results shown here may not be applicable to advanced PD patients"* • Better oral hygiene, with a **higher frequency of toothbrushing** in PD patients • Preference for **soft food** (71% vs 43%), less inter-meal habits than control (female subgroup) • No difference from controls as to salivary flow and pH
Hanaoka & Kashihara, 2009 [10] /Japan	• N=89 (38 males), mean age 72.1 ± 5.5 (60-79) y, mean PD duration 5.9 ± 5.0 y, mean LEDD 453 ± 232 mg/day • Compared to similar age (but unmatched) control groups with 68 (26 males) patients with mild neurological disease, mean age 69.0 ± 5.8 y & 60 (37 males) patients with acute & ischemic stroke, mean age 70.9 ± 5.4 y (PD patients were older compared to control group)	• PD group characteristics: ➢ Higher frequency of **untreated caries** (average number 1.9 ± 3.3, ranging from 1 to 22), significantly higher at Hoehn & Yahr stages 2 to 5 (>40% at Hoehn & Yahr stage 2) and a higher tendency in PD patients with lower cognitive scores (MMSE) ➢ Higher frequency of **periodontal pockets** (depth > 4mm) in PD group (98.6%) compared to the other groups (43.5% for mild neurological disease & 41.2% for stroke) ➢ **Fewer number of remaining teeth** (no association with PD duration or LEDD) • "Frequencies of caries and periodontal disease were **high even in the early stage of those patients with PD in patients who showed no functional disability in their daily activities**."
Kennedy et al., 1994 [11] /USA	• N= 28 (16 males) ambulatory, non-demented PD patients, divided into 2 groups: (1) "crave sweets": N=14 (9 males), mean age 65.7 ± 6.2 y, mean PD duration 8.6 ± 5.0 y,	• **No significant differences between groups on decayed, missing, and filled teeth (DMFT), oral hygiene level & gingivitis** • Significantly higher levels of **mucositis** in PD group compared to control group (but no difference between both PD groups) • Significantly **higher *Streptococcus mutans* percentage in both PD groups** (authors hypothesis: "*may be due to the fact that many PD patients are on medications that produce xerostomia as a side-effect*")

	mean Hoehn & Yahr stage 3.1 ± 0.77 (2) "not crave sweets" N=14 (7 males), mean age 67.6 ± 9.2 y, mean disease duration 9.4 ± 5.5 y, mean Hoeh & Yahr stage 2.9 ± 0.83 • Compared to 14 (6 males) "controls of comparable age and sex", mean age 64.1 ± 6.8 y • Objective assessments	• No significant correlation between the microflora and the clinical assessments
Lyra et al., 2020 [12] /Portugal	• N= 28 (23 males), mean age 72.3 ± 8.1 y; idiopathic PD (82.1%) *or other parkinsonisms*; mild to severe motor impairment • No control group • Objective & subjective assessments	• **High prevalence of periodontitis** (75%), with a majority (46.4%) of severe (stage III) periodontitis (possible confounding factors: age, male sex, smoking habits) Average of 12 **missing teeth** (the more teeth lost, the worse the speech & eating ability) and of 1 tooth with **pathological mobility** 37,0 ± 29.4% of **plaque** and 19.3 ± 21.1% of **gum inflammation** in the whole mouth • Oral hygiene: **75% manual toothbrush**, 64.3% with **last dental visit within the last 6 months** • **Likely association between PD progression & impaired oral hygiene habits**: worse periodontal status (increased plaque accumulation, gum bleeding & deepest periodontal pockets) significantly correlated with **upper extremity rigidity, hand posture and kinetic tremors** • PDQ-8 showed to be correlated with self- perceived oral health-related quality of life and xerostomia levels
Müller et al., 2011 [13] /Germany	• N= 101 (55 males), mean age 66.2 ± 10.5 y; **Hoehn & Yahr stages 1–4** (mean 2.72 ± 0.84), neurological "in-patients for diagnosis or optimization of their PD drug therapy" • Compared to 75 unmatched control subjects from a private dental practice (older, different sex ratio) • Objective & subjective assessments, including a blind assessment (clinical status/dental hygienist)	• **Poorer oral health** compared to controls • Dental status: more **dental crown & decayed teeth** • Periodontal disease: more severe **periodontal disease**, and more **periodontal pockets**, **tooth mobility**, and **gingival recession** compared to controls (in both male and female PD patients) • Oral care: **lower frequencies of toothbrushing & dental visits** • Impaired oral self-cleaning mechanisms: **reduced salivary flow**
Nakayama et al., 2004 [14] /Japan	• N=104 (44 males) PD patients, aged > 60 y, **Hoehn & Yahr stages 3–5**	• **More complaints with oral health & more problems in oral health behavior in the PD group** ➢ **Chewing difficulties** (regardless of sex and age) & complaints about **food impaction** (but lack of knowledge regarding interdental cleaning in the PD group) ➢ Higher number of **edentulous** patients (regardless of sex and age)

	• Compared to 191 (78 males) controls aged > 60 y who got dental check-ups • Objective & subjective assessments	**Denture discomfort** (regardless of sex and age), **less daily cleaning of denture** (regardless of sex and age), **less dentures checkups** (30% of PD patients had never gone to a dental clinic after their dentures had been made) **Swollen gums** in the "young elderly" PD patients ➢ Conditions of oral health: **trouble with toothbrushing or denture cleaning** (49%), ability to brush their teeth by themselves (65%), ability to remove & put dentures by themselves (82%), ability to gargle (60%), **swallowing disorders** (54%, various degrees of severity) **Few PD patients had knowledge of brushes for cleaning dentures** (19%), coating of the tongue (14%) **or dental floss** (3%) • Access to dental care: **14% unable to go to a dental clinic in any case, 48% unable to go to a dental clinic alone** (needing assistance by family members/helpers or transportation service by car) 28% "looking forward to have a dental check-up and toothbrushing instructions" (**home-visiting dental service**)
Persson et al., 1992 [15] /Sweden	• N=30 (17 males), mean age 73 ± 7.3 y, mean PD duration 11 ± 5.4 (4-19) y. All patients treated with dopaminergic drugs; 13 patients with fluctuating symptoms • Control group: "population sample" of 585 70-year-old subjects (longitudinal geriatric population studies) • Objective & subjective assessments	• Good dental status, more remaining teeth and lower prevalence of caries in the PD groups compared to a representative population of corresponding age (authors' hypotheses: "general conscientiousness in patients and relatives") No differences between PD and control group for oral complaints (except for **swallowing disorders**) & frequency of dental care • Insignificantly higher salivary secretion in PD group compared to control Significantly higher salivary flow in PD patients **treated with L-dopa as monotherapy compared to those treated with other antiparkinsonian drugs as well.** No difference between patients taking anticholinergic drugs & patients taking dopamine agonists; decreased saliva secretion rate with increasing hypokinesia • **Difficulties in performing oral hygiene (47%), correlated to the severity of hypokinesia** Considered by a majority of patients to be related to "different aspects of hypokinesia, such as slowness in the hands, decreased strength, and poor coordination", involuntary movements, hand tremor and/or dementia
Pradeep et al., 2015 [16] /India	• N=45 (30 males) consecutive PD patients, mean age 64.5 ± 9.1 y (50-79), divided into 5 groups according to Hoehn & Yahr stages 1- 5 • Compared to 46 (28 males) age-matched control subjects (PD patients' partner or close family member), mean age 63.9±1.1 y • Inclusion criteria: > 10 teeth • Objective (blinded) & subjective assessments	• **Deteriorating dental condition** in PD patients compared to controls, with a **worsening of periodontal condition with increased PD severity** (significant increase of all the periodontal clinical parameters and indices) *"Periodontal health of subjects with PD starts deteriorating in very early stages. Even in the Hoehn and Yahr stage 1, all the evaluated parameters showed significant difference"* • Dental care characteristics: toothbrushing (with toothpaste) at least once a day (75.6%), brush changes every 6 months, flossing (13.3%), mouthwash (35.6), dental visits > once/year (28.8%)

Ribeiro et al., 2016 [17] /Brazil	• N= 17 (9 males) removable prosthesis wearers PD patients, mean age 69.6 ± 5.1 y, mean PD duration 6.8±3.8 y, daily levodopa treatment (not stratified by disease severity) • N= 20 removable prosthesis control, mean age 72.0 ± 5.7 y, "chosen among friends & relatives of PD patients or from elders who sought prosthetic treatment at the dental clinic" • Objective & subjective assessments	•**More negative self-perceptions of oral health in the PD group**, despite similar oral health to controls (no group differences in the number of remaining teeth, DMFT, VPI or salivary flow rate) and having fewer defects in the maxillary prostheses than controls: *"the motor symptoms of PD may explain the more negative self-perception of oral health"* • **Few remaining teeth** in both groups Authors' hypotheses: *"Since greater severity of PD predisposes individuals to a poorer state of oral health, **these contrasting results may be due to inclusion of patients with different degrees of PD severity**, which was not recorded in the present study"*
Schwarz et al., 2006 [18] /Germany	• N= 70 (39 males), mean age 64.5 years (48-75), undetailed PD clinical parameters • Compared to 85 (41 males) age-matched control subjects, randomly recruited among subjects seeking routine dental counselling, mean age 62 y (50-78) • Objective assessment (N=1)	• **Increased periodontal pathology in PD**, with significant difference between the Community Periodontal Index for Treatment Needs (CPITN) scores (++ **upper frontal teeth**) → "may point towards **the impairment of motor skills being the primary risk factor**" • In contrast with control, "trend" towards higher CPITN indices in **female** patients compared with male patients (authors' hypotheses: sample bias?)
van Stiphout et al., 2018 [19] /Netherlands	• N= 74 (48 males), mean age 70.2 ± 8.8 y, mean disease duration 9.1 ± 6.4 y, Hoehn & Yahr stages 1-5 • Compared to 74 optimally gender-, age-, social background-, and lifestyle-matched controls, mean age 67.9 ± 10.1 y • Objective & subjective assessments	• Weakened oral health status & reduced oral hygiene care: • Oral care: less than half a year since the last oral health consultation (70.3%), 94.6% with at least one oral health consultation during the previous 5 y; **14.9% assisted daily oral hygiene care** (professional or care provider), 48.6% electric toothbrush use • Oral health complaints (* significantly different from controls): remaining food particles (70.3%), **xerostomia*** (64.9%), **biting problems*** (35.1%), **chewing problems*** (29.7%), **taste disturbance*** (23.0%), halitosis (18.9%), burning mouth (4.1%). In dentate patients: tooth sensitivity (26.2%), bleeding gums (20.0%), **tooth mobility*** (18.5%), painful gums (18.5%), toothache (15.4%) • Oral health status: greater number of teeth with **carious lesions**, **tooth root remnants**, and greater amount of **biofilm** and food when compared to the (dentate) control subjects • **Disease severity & duration were associated with more oral health and hygiene care problems** (chewing/biting problems, teeth with restorations and/or mobility)

LEDD, levodopa equivalent daily dose; PD, Parkinson's disease

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