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3	Probing single-tooth dental implants with and without prostheses. A cross-sectional
4	study comparing healthy and peri-implant mucositis sites.
5	Running Title: Probing implants with/without prostheses
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10 The data that support the findings of this study are available from the corresponding11 author upon reasonable request.

12

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1 Abstract

Aim: To evaluate differences in probing depth (PPD) with and without a prosthesis in implants without interproximal bone loss (IBL). Secondarily, to assess whether the difference in PPD measured with and without the crown was affected by diagnosis or implant location.

Materials and Methods: A cross-sectional study was conducted in patients with a single
screw-retained implant-supported crown in the posterior area, without IBL. PPD and was
assessed before and after crown removal. A subgroup analysis compared healthy vs.
mucositis implants and premolar vs. molar locations.

Results: In the 62 implants analysed (23 healthy and 39 with mucositis), the PPD was 1.15 mm (SD=1.24 mm) deeper without the prosthesis than with it (p<0.001). This difference was independent of the implant location (p>0.05) except for buccal sites (p=0.048). The mean PPD difference for implants with mucositis was 0.95 mm (SD=1.19mm)(p<0.001) while healthy implants had a mean PPD variation of 1.47 mm (SD=1.29mm)(p<0.001).</p>

16 **Conclusion:** The presence of prosthesis in single tooth implants in the posterior area 17 without IBL seems to lead to an underestimation of PPD that appears to be significant in 18 implants diagnosed with mucositis, although the difference is even greater in healthy 19 implants. Further studies are needed to confirm these findings.

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Keywords: Single-tooth dental implant, probing, diagnosis, implant-supported dental
 prosthesis, peri-implantitis.

23

1 Clinical relevance

2 Scientific rationale for study: Periodontal probing depth (PPD) is an essential clinical
3 examination method for the diagnosis of peri-implant diseases. Nevertheless, probing
4 without removing the prosthesis might lead to an incorrect clinical assessment.

5

Principal findings: In single-tooth implants, overall, PPD with the prosthesis in place was
1.15 mm (SD=1.24 mm) less than PPD without the prosthesis. Significant
underestimations were found in both healthy sites (1.47 mm; SD=1.29mm) and implants
with mucositis (0.95 mm; SD=1.19mm).

11 *Practical implications:* The presence of the prosthesis may lead to an unprecise recording

12 of PPD at implant sites.

1 Introduction

Peri-implantitis and mucositis are plaque-related pathological conditions affecting the
tissues around dental implants (Berglundh et al., 2018). Probing is a fundamental
examination tool for monitoring peri-implant tissue status. It detects bleeding and
changes in pocket depth (Lindhe & Meyle, 2008) (Klinge, Hultin, & Berglundh, 2005).
Higher periodontal probing depth (PPD) measurements can be related to soft tissue
inflammation, bone loss, or both (Berglundh et al., 2018).

8 The technique for probing dental implants is the same as for probing teeth, but anatomical 9 and structural differences lead to slight differences in the interpretation of the results 10 (Schou et al., 2002) (Abrahamsson & Soldini, 2006). Indeed, several studies have 11 reported PPDs of >4mm in healthy implants (Bergenblock, Andersson, Fürst, & Jemt, 12 2012). Factors such as peri-implant probing force (Gerber, Tan, Balmer, Salvi, & Lang, 13 2009), periodontal probe thickness and angulation (Salvi & Lang, 2004), repeated PPD 14 measurements (Coli & Sennerby, 2019), apico-coronal position of the implant (Grunder, 15 Gracis, & Capelli, 2005), inflammation (Schou et al., 2002), presence of an adjacent 16 natural tooth (Serino, Turri, & Lang, 2013), implant design (Hermann, Buser, Schenk, 17 Schoolfield, & Cochran, 2001), or the presence of the prosthesis (Serino, Turri, & Lang, 18 2013) all have an impact upon PPD, and a numerical threshold for "healthy" or 19 "pathological" appears not to exist. In implants without interproximal bone loss (IBL), 20 PPD is likely to be related to soft tissue thickness. For this reason, when probing around 21 implants, bleeding on probing (BOP) has been considered a more reliable tool than PPD 22 for detecting inflammation (Renvert, Persson, Pirih, & Camargo, 2018).

23

24 PPD can also be affected by the prosthesis design (Dixon & London, 2019). When the 25 crown is considerably wider than the implant or the crown is overcontoured, the PPD

1 measurement can be unreliable. In fact, Serino et al. (Serino, Turri, & Lang, 2013) only 2 found a good correlation between PPD and marginal bone loss (MBL) when the implant was probed without the prosthesis. However, their study included patients with several 3 4 types of edentulism and marginal bone loss occurred at all the implant sites. Despite 5 probing being an essential tool for dental implant follow-up and diagnosis (Berglundh et 6 al., 2018), no studies have assessed the effect of not removing the prosthesis before 7 measuring PPD in patients with single-tooth restorations without IBL. Because of this, 8 the main objective of this study was to detect differences in PPD with and without the 9 prosthesis in single-tooth implants without IBL in the posterior areas. A secondary aim 10 was to assess whether the difference in PPD measured with and without removing the 11 crown was affected by diagnosis (health vs mucositis) or implant location (premolar vs. 12 molar).

13

14 Material and methods

15 A cross-sectional study was performed in patients treated consecutively at the University 16 of Barcelona Implant Maintenance Unit (Master of Oral Surgery and Orofacial 17 Implantology), between June 2013 and October 2018. Several dentists were involved in 18 the surgical and prosthetic treatment of these patients.

19

20 Eligibility criteria

The inclusion criteria were patients having at least one single-tooth implant placed at crestal level, without a polished collar, without radiographically detected IBL (the distance measured from the most coronal part of the rough surface of the implant to bone level was less than 3mm (Renvert et al., 2018)), with a screw-retained restoration connected to the implant without an intermediate abutment, in the posterior area of the 1 mouth (premolar to molar) and with a clinical follow-up of at least 1 year from prosthetic

2 loading.

The diagnostic criteria of the 2017 World Workshop on the Classification of Periodontal
and Peri-Implant Diseases and Conditions (Berglundh et al., 2018) were applied, as
follows:

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 Healthy: Absence of clinical signs of inflammation. Absence of bleeding and/or suppuration on gentle probing. Without increased PPD in comparison with previous observations. Absence of IBL beyond changes attributed to initial osseous remodelling.

Mucositis: Presence of bleeding and/or suppuration on gentle probing,
 without increased PPD when compared with previous observations, and
 absence of IBL beyond changes attributed to initial bone remodelling.

In patients with more than 1 single-unit implant that fulfilled the inclusion criteria, theimplant with more locations with bleeding on probing (BOP) was selected.

The exclusion criteria were implants with a clear malposition (mesio-distal, apico-coronal and buco-lingual directions), implants placed in incisor or canine positions, implants with soft tissue recessions, cemented crowns, crowns that could not be removed and implants with peri-implantitis. Implants with polished collars and restorations with intermediate abutments were also excluded to limit the effect of possible confounders like the implant design on the PPD measurements.

21

22 Ethical issues

The study was approved by the Bioethics Institutional Review Board of the University of
Barcelona (Ref.IRB00003099). The researchers followed the recommendations of the
Declaration of Helsinki: Ethical Principles for Research involving Human Subjects

(World Medical Association, 2013) and the STROBE guidelines for reporting cross sectional studies (Vandenbroucke et al., 2007). Before inclusion, all the subjects gave
 their informed consent.

4

5 *Study sequence*

6 In a single visit, a single experienced researcher (MGG) registered the following 7 variables: age, gender, date of implant placement, tobacco consumption and implant 8 position. At the same session, the researcher gently probed the selected single-tooth 9 implant using a manual PCP15 periodontal probe (Hu-Friedy Inc., Leimen, Germany) 10 and registered the following variables from 6 sites per implant: mesiobuccal, buccal, 11 distobuccal, mesiolingual, lingual, distolingual.

12 **Before removal of the prosthesis:**

Measurement of PPD1: The PPD at each site was measured as the distance from the
 mucosal margin to the base of the peri-implant sulcus/pocket. The mean PPD per
 implant was also computed.

16 - Bleeding on probing (BOP): Presence or absence of bleeding after gentle probing.

17 - Mombelli modified plaque index (mPI): (Mombelli, Oosten, Schürch, & Lang,
18 1987).

Keratinized mucosa (KM): distance from the mucosal margin to the mucogingival
 junction at the mesiobuccal site of each implant.

21

22 After removal of the prosthesis:

Measurement of PPD2: The PPD at each site was measured as the distance from the
 mucosal margin to the base of the peri-implant sulcus/pocket. This measurement was

registered after obtaining the periapical radiography and removing the prosthesis. The
 mean PPD per implant was also calculated.

Distance between implant shoulder and mucosal margin (DIM): Distance from the mucosal margin to the implant shoulder (connection). Sites where the mucosal margin was apical to the implant shoulder were considered recessions. Implants with recessions were excluded. At sites where the mucosal margin was coronal to the implant shoulder, the term "transmucosal height" was employed and DIM was registered (Buser, Weber, & Lang, 1990).

10 The mean value for each implant was also calculated (Supplementary Table 1).

Attachment level (AL): This was computed for each site by adding the PPD2 and
 DIM values together (Buser et al., 1990) (Supplementary Figure 1). The mean value
 per implant was also calculated (Supplementary Table 1).

Difference between PPD with and without prosthesis (main outcome variable): The differences between the measurements performed with the prosthesis in place (PPD1) and after removing the crown (PPD2) were calculated as PPD1-PPD2 for each site (6 sites per implant) and the mean of each implant. This variable was also used to compare implants located in molars vs. premolars, and healthy implants vs. implants with mucositis (secondary outcomes).

20

The implants were cleaned with plastic curettes (Implantcare ® II, Hu-Friedy, Chicago, IL, USA) and irrigated with 0.12% chlorhexidine gluconate and 0.05% cetylpiridinium chloride (Perio-aid treatment®, Dentaid SA, Cerdanyola del Vallès, Spain). The prosthesis was removed and the crowns were cleaned and recontoured in the areas that interfered with oral hygiene (Tapia et al., 2019). Finally, the crowns were placed back in position, the researcher instructed the patients in the effective use of a toothbrush and
 interproximal brushes and the patients were included in an implant maintenance
 programme.

4

5 To test intra-examiner agreement, the assessment of seven implants was repeated after 2 6 weeks. The calibration measurement were PPD1 and PPD2 at 6 sites per implant 7 (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, distolingual). The intra-class 8 correlation coefficient (ICC) was 0.93 for PPD1 [95% confidence interval (CI) 0.88 to 9 0.93] and 0.94 for PPD2 [95% confidence interval (CI) 0.88 to 0.97].

10

11 Sample size calculation

12 Sample size was calculated using G * Power 3.0. (Heinrich-Heine-Universität, 13 Dusseldorf, Germany) (Faul, Erdfelder, Buchner, & Lang, 2009) and considering the 14 outcomes published by Serino et al. (Serino, Turri, & Lang, 2013). To detect an intra-15 group difference of 1 mm between PPD1 and PPD2 with a standard deviation (SD) of 16 2mm, a 5% alpha error and 90% power, 44 patients would be needed. The present study 17 did not include patients with peri-implantitis, so the PPDs values might be slightly 18 different in comparison with the ones published by Serino et al. (Serino, Turri, & Lang, 19 2013). Since this issue could increase the variability of the results, the total sample was 20 increased to 62 patients.

21

22 Statistical analysis

23 The data were processed using IBM SPSS 25.0 (IBM, NY, USA). PPD1, PPD2, BOP,

24 mPI, KM, DIM and AL were measured at the 6 sites around each implant. BOP was used

25 to classify implants into healthy or mucositis.

Paired t-tests were used to compare the differences between PPD1 and PPD2 for each
 implant site and each implant. An independent sample t-test was performed to detect
 differences in PPD between subgroups (healthy versus mucositis; premolars versus
 molars). Results showing p≤0.05 were considered statistically significant.

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- 6

7 **Results**

Of the 73 patients screened, 2 were excluded because they had intermediate abutments, 7 because of a diagnosis of peri-implantitis and 2 because the implant had a buccal dehiscency (soft tissue recession). Consequently, 62 patients were included, of whom 39 had mucositis and 23 were healthy. Thirty patients had been treated at private dental practices and 32 had restorations performed by postgraduate students of the University of Barcelona. A total of 372 sites were examined, all of which could be probed with and without prosthesis.

15 The main characteristics of the sample can be observed in Table 1. The distribution by 16 gender was 33 female and 29 male, with a mean age of 54 years (SD=12.0 years). Ten patients were smokers. Thirty implants were in the maxilla and 32 in the mandible. 17 18 Twenty implants were located in the premolar area and 42 in the molar region. The 19 implant connection was internal in 38 cases and external in 24. The mean follow-up time 20 after loading was 71.0 months (SD=29.0 months). The mean mPI was 0.3 (SD=0.9), the 21 mean KM was 2.2 mm (SD=1.0 mm), the mean DIM was 2.80mm (SD=1.43 mm) and 22 the mean AL was 1.59mm (SD=0.51 mm) (Supplementary Table 1). No suppuration was 23 observed at any of the implant sites.

The PPD values with (PPD1) and without (PPD2) the prosthesis are shown in Table 2.
 PPD1 was significantly smaller than PPD2 at all 6 implant sites, with a mean difference
 of 1.15 mm (SD= 1.24mm) (p<0.001).

The difference between PPD1 and PPD2 was 0 at 88 sites (23.6%). Overestimation was
up to 1 mm at 48 sites (12.9%). Underestimation occurred between 1 and 3 mm at 210
sites (56.5%), between 4 and 6 mm at 25 sites (6.7%) and more than 6 mm at 1 site (0.3%).
(Figure 1) (Supplementary Table 2).

8

9 Subgroup analysis

Patients with mucositis had a significantly higher mPI (p = 0.003). Fifty-four percent of the implants with mucositis had bleeding at only 1 site.

12 Mean periodontal probing depths in healthy and mucositis subgroups are shown in Table 13 3. In both subgroups, the mean PPD2 was significantly deeper than the mean PPD1 (Table 14 4). These differences between PPD1 and PPD2 were higher in the healthy implants 15 (1.47mm; SD=1.29) in comparison with mucositis sites (0.95mm; SD=1.19) (Table 4). 16 Table 4 also reveals that PPD1 differed significantly in implants with mucositis compared 17 with healthy implants (p=0.004). Figure 1, Figure 2 and Supplementary Table 2 show 18 how the difference between PPD1 and PPD2 was distributed in both groups. 19 At 334 sites (89.8%) the implant shoulder was below the gingival margin, with no 20 difference between healthy implants (91.3%; 126 sites) and implants with mucositis

21 (88.9%; 208 sites). At the remaining sites the gingival margin was level with the implant

22 shoulder (Supplementary Table 3).

- 1 The difference between PPD1 and PPD2 was similar for premolars and molars, with one
- 2 exception: at the buccal sites, the difference was significantly greater in premolars
- 3 (1.5mm vs. 0.7mm in molars) (p=0.048) (Table 5).

1 **Discussion**

2 The results of this study indicate that in posterior implant-supported single-tooth 3 restorations, the crown interferes with PPD measurement leading to a mean 4 underestimation of 1.15mm (SD=1.24). This difference is observed in both locations 5 (premolar and molar regions) and is higher in healthy implants although it could also be 6 observed in implants with mucositis. It is also important to stress that the underestimation 7 of PPD with the prosthesis in place was more than 2mm at 38% of the sites, which, from 8 a clinical perspective, may be considered a significant finding (Figure 1 and 9 Supplementary Table 2). Nonetheless, these results do not necessarily indicate the need 10 to remove the crown for probing since the diagnosis of healthy or mucositis implants is 11 not influenced by the PPD.

12

13 As the main diagnostic criterion for mucositis is BOP (Heitz-Mayfield & Salvi, 2018), 14 the presence of bleeding would be a sufficient criterion for diagnosing mucositis with the 15 prosthesis in place despite the risk of underestimating the PPD value. Future studies 16 should ascertain whether probing without removing the prosthesis allows good 17 monitoring of implant health, as an increase in PPD over time might indicate disease 18 progression (Klinge et al., 2005) (Renvert et al., 2018). The present study showed that 19 healthy peri-implant sites had lower PPD values when the prosthesis was present. This 20 might be explained by the fact that a healthy soft tissue will impede probe penetration 21 (when a gentle force is applied), while following the removal of the crown, the mucosa 22 height can be measured more accurately. In contrast, the tissues at mucositis sites may be 23 less resistant to probe penetration, which might account for their smaller difference 24 between PPD1 and PPD2 (Table 4).

1 The crown profile may impede or facilitate probe penetration. The reason why the 2 difference between PPD1 and PPD2 was significantly higher only on the buccal side of 3 premolars could be related to the crown contour. Since premolars are more visible, 4 overcontouring of the buccal aspect might be necessary to improve the aesthetic outcome. 5 Indeed, recent publications report that the prosthesis can be a possible risk factor for peri-6 implant diseases, as it interferes with access for oral hygiene (Serino & Ström, 7 2009)(Chaves, Lovell, & Tahmasebi, 2014)(Katafuchi, Weinstein, Leroux, Chen, & 8 Daubert, 2018)(Serino & Hultin, 2019). Prostheses with a marked convexity or overhang 9 can stop or divert the periodontal probe (Dixon & London, 2019). Since the protocol of 10 the present study included recontouring the crowns to facilitate oral hygiene, it is likely 11 that this manoeuvre also improved the probing access. Future research should try to 12 determine whether appropriate prosthetic design might reduce the observed differences 13 between PPDs with and without crowns.

In this study, the PPD could be measured around all the implants with prostheses because they had all been restored with single crowns (Dixon & London, 2019). Bridges, cantilevers or full-arch restorations can interfere with probing, making it impossible unless the prosthesis is removed (Serino, Turri, & Lang, 2013).

18 Transmucosal height was recorded at almost 90% of sites, with a mean of 2.80 mm 19 (SD=1.43mm) (Supplementary Table1). Since the anatomy of the periodontum is 20 different from that of a healthy implant (Ivanovski & Lee, 2018), the depth of the 21 transmucosal height is probably related more to the thickness of the soft tissue than to 22 swelling. Thus, it is unclear whether a high PPD value without IBL might be a risk factor 23 for the development of peri-implant diseases. Still, it might be hypothesised that a greater 24 PPD could lead to the development of a more anaerobic environment (Kröger et al.,

- 2018). It could be of interest to record the position of the mucosal margin during the peri implant maintenance appointments to detect clinical changes.
- 3

4 Points of agreement and disagreement with previous studies

5 A previous paper (Serino et al., 2013) comparing PPD1 and PPD2 reported better 6 correlation with the actual bone level in PPD2. In the present study, the PPD2 values were 7 lower than those reported by Serino et al. (Serino et al., 2013) (4.39 mm \pm 1.33 mm Vs. 8 5.80 mm \pm 2.30 mm). This is probably related to the fact that the present sample did not 9 include patients with IBL. This might also explain why Serino et al. (Serino, Turri, & 10 Lang, 2013) only found differences in the PPD at the buccal site, since implants with peri-11 implantitis tend to present a higher bone loss at this location (Schwarz et al., 2007) 12 (García-García, Mir-Mari, Benic, Figueiredo, & Valmaseda-Castellón, 2016).

13

14 Limitations and recommendations for future studies

15 For monitoring peri-implant soft tissue position, a fixed reference point that allows 16 reproducibility of the same measurements over time must first be determined. 17 Considering that this reference point depends on the implant system and its prosthesis, 18 clear references to these measurements in implants without a transmucosal polished collar 19 and with direct-to-implant restorations were sought but not found. In the present study, 20 terminology established by Buser et al. in 1990 (Buser et al., 1990) was adapted to the 21 parameters measured. This might be a limitation since it makes comparisons with other 22 studies more difficult.

The patients included in the present sample were treated by several dentists at different clinics. This can be considered a limitation since it was not possible to gather some relevant data relating to the surgical and prosthetic treatment (for example, the dentist's experience and training and whether surgical guides were used, among other questions).
 On the other hand, this variability could increase the external validity of the study
 findings. Also, it is important to stress that all the patients had screw-retained prostheses,
 which might reflect a fairly accurate implant position.

5 Another limitation of this study was that it only included patients without IBL and with 6 single-tooth implant restorations. It would be interesting to compare differences in PPD 7 with or without restorations in patients with different types of prosthesis (single-units and 8 bridges; prosthesis with and without intermediate abutments, overcontoured crowns, 9 etc.), different implant designs and in cases with peri-implantitis. Also, the effect of 10 smoking on PPD could not be assessed due to the limited number of smokers in the 11 sample. Another factor that should be addressed in future research is related to the 12 location of the implant. In the present study, anterior implants were excluded as the crown 13 contour may be a confounder because of the need to hide the connection. Finally, in this 14 study a single calibrated experienced examiner made all the measurements with a manual 15 probe, so the probing force was not controlled.

16

17 Conclusion

18 The presence of the prosthesis seems to lead to significant underestimation of the 19 probing depth (PPD), by between 0.83 and 1.46 mm in posterior single-tooth implants 20 without interproximal bone loss. This underestimation appears to be significant in 21 implants diagnosed with mucositis, although it is even higher in healthy implants. The 22 difference in PPD measured with and without removing the crown is not affected by 23 implant location (molar/premolar). These findings should be interpreted with caution due 24 to the limitations of this study and its cross-sectional design.

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7	

1 Tables

Mean age (years)	53.44 (SD=11.9)					
Gender						
Female: <i>n</i> (%)	33 (53.2%)					
Male: <i>n</i> (%)	29 (46.8%)					
Smoking						
Non-smoker: n (%)	52 (83.9%)					
Smoker: <i>n</i> (%)	10 (16.1%)					
Loca	tion					
Maxilla: <i>n</i> (%)	30 (48.4%)					
Mandible: <i>n</i> (%)	32 (51.6%)					
Connection						
External: n (%)	24 (38.7%)					
Internal: <i>n</i> (%)	38 (61.3%)					
Plaque index and k	keratinized mucosa					
Mean mPI	0.34(SD=0.9)					
Mean KM (mm)	2.23 (SD=1.03)					
Diag	nosis					
Healthy: <i>n</i> (%)	23 (37.1%)					
Mucositis: <i>n</i> (%)	39 (62.9%)					
Position						
Molar: <i>n</i> (%)	42 (67.7%)					
Premolar: n (%)	20 (32.3%)					

2
 Table 1. Main characteristics of the sample.

3 4

mPI: Modified Plaque Index; KM: Keratinized mucosa; SD: Standard deviation

	PPD1		PPD2		Differe	Bivariate analysis	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	(p)
Mesiobuccal	3.40	[3.09; 3.71]	4.55	[4.14; 4.95]	-1.15	[-1.57; -0.72]	< 0.001
Buccal	2.97	[2.71; 3.22]	3.89	[3.55; 4.22]	-0,92	[-1.30; -0.54]	< 0.001
Distobuccal	3.32	[2.97; 3.67]	4.42	[4.02; 4.82]	-1.10	[-1.53; -0.66]	< 0.001
Mesiolingual	3.24	[2.95; 3.54]	4.44	[4.07; 4.80]	-1.19	[-1.55; -0.83]	< 0.001
Lingual	3.03	[2.80; 3.27]	4.29	[3.90; 4.68]	-1.26	[-1.66; 0.85]	< 0.001
Distolingual	3.47	[3.13; 3.80]	4.73	[4.25; 5.20]	-1.26	[-1.71; 0.81]	< 0.001
Mean	3.24	[3.01; 3.46]	4.38	[4.05; 4.72]	-1.15	[-1.46; -0.83]	< 0.001

1
Table 2. Mean periodontal probing depths in mm.

PPD1: periodontal probing depth with prosthesis; PPD2: periodontal probing depth without prosthesis; 95 % CI: 95 % confidence interval. Bold-faced p-values are statistically significant

		Н	=23)	Mucositis (n=39)						
	PPD1		PPD2		Bivariate analysis	PPD1		PPD2		Bivariate analysis
	Mean	95% CI	Mean	95% CI	(P)	Mean	95% CI	Mean	95% CI	(p)
Mesiobuccal	2.96	[2.60; 3.31]	4.44	[3.75; 5.12]	< 0.001	3.67	[3.23; 4.10]	4.62	[4.09; 5.14]	0.001
Buccal	2.39	[2.08; 2.70]	3.78	[3.25; 4.32]	< 0.001	3.31	[2.98; 3.63]	3.95	[3.50; 4.39]	0.009
Distobuccal	2.91	[2.33; 3.49]	4.48	[3.79; 5.17]	< 0.001	3.56	[3.13; 4.00]	4.38	[3.87; 4.90]	0.003
Mesiolingual	2.78	[2.33; 3.23]	4.57	[3.93; 5.20]	< 0.001	3.51	[3.14; 3.88]	4.36	[3.90; 4.82]	< 0.001
Lingual	2.78	[2.39; 3.17]	4.13	[3.57; 4.69]	< 0.001	3.18	[2.88; 3.48]	4.38	[3.85; 4.92]	< 0.001
Distolingual	3.26	[2.66; 3.86]	4.57	[3.81; 5.32]	0.002	3.59	[3.18; 4.00]	4.82	[4.19; 5.45]	< 0.001
Mean PPD	2.85	[2.55; 3.15]	4.33	[3.79; 4.86]	< 0.001	3.47	[3.18; 3.76]	4.42	[3.96; 4.87]	< 0.001

Table 3. Mean periodontal probing depths in healthy and mucositis groups, in mm.

3 4 5 PPD1: periodontal probing depth with prosthesis; PPD2: periodontal probing depth without

prosthesis; 95 % CI: 95 % confidence interval. Bold-faced p-values are statistically significant

Table 4. Differences between periodontal probing depths with and without prostheses in

	Healthy (n=23)	Mucositis (n=39)	Difference	Bivariate analysis
		Mean [95% CI]		р
PPD1	2.85 [2.55; 3.15]	3.47 [3.18; 3.76]	-0.62 [-1.06; -0.18]	0.004
PPD2	4.33 [3.79; 4.86]	4.42 [3.96; 4.87]	-0.09 [-0.77; 0.59]	0.787
Mean difference	-1.48 [-2.04; -0.92]	-0.95 [-1.33; -0.56]		0.115
Bivariate analysis (p)	<0.001	<0.001		
	Probing difference (PPD1-PPD2) Mean [95% CI]		Bivariate ana (p)	lysis
Mesiobuccal	-1.48 [-2.21; -0.74]	-0.95 [-1.47; -0.42]	0.235	
Buccal	-1.39 [-2.04; -0.74]	-0.64 [-1.11; -0.17]	0.061	
Distobuccal	-1.57 [-2.35; -2.35]	-0.82 [-1.35; -0.30]	0.111	
Mesiolingual	-1.78 [-2.43; -1.13]	-0.85 [-1.26; -0.44]	0.016	
Lingual	-1.35 [-2.03; 0.66]	-1.21 [-1.74; -0.67]	0.737	
Distolingual	-1.30 [-2.06; -0.55]	-1.23 [-1.82; -0.64]	0.875	

healthy and mucositis subgroups.

PPD1: periodontal probing depth with prosthesis; PPD2: periodontal probing depth without prosthesis; 95 % CI: 95 % confidence interval. Bold-faced p-values are statistically significant

1 Table 5. Differences between periodontal probing depths with and without prostheses in

2	premolars and molars	S
7	premotars and motars	5.

	Premolar (n=20)	Molar (n=42)	Difference	Bivariate analysis
	Ν		(p)	
PPD1	3.33 [2.95; 3.72]	3.19 [2.91; 3.48]	0.14 [- 0.33; 0.61]	0.552
PPD2	4.71 [4.17; 5.25]	4.23 [3.79; 4.66]	0.48 [- 0.24; 1.20]	0.162
Mean difference	-1.38 [-1.85; -0.90]	-1.04 [-1.45; -0.62]	0.34 [- 0.28; 0.96]	0.274
Bivariate analysis (p)	<0.001	<0.001		
	Probing difference Mean [95% CI]		Bivariate analysis (p)	
Mesiobuccal	-1.00 [-1.59; 0.41]	-1.21 [-1.79; -0.65]	0.5	93
Buccal	-1.45 [-2.08; -0.82]	-0.67 [-1.14; -0.19]	0.04	48
Distobuccal	-1.20 [-1.89; -0.51]	-1.04 [-1.62; -0.48]	0.72	27
Mesiolingual	-1.40 [-2.00; -0.80]	-1.10 [-1.56; -0.63]	0.4	10
Lingual	-1.60 [-2.39; -0.81]	-1.10 [-1.58; -0.61]	0.20	59
Distolingual	-1.60 [-2.38; -0.82]	-1.10 [-1.67; -0.53]	0.23	87

PPD1: periodontal probing depth with prosthesis; PPD2: periodontal probing depth without prosthesis; 95 % CI: 95 % confidence interval, Bold-faced p-values are 3 4 5 6 statistically significant

1 **Figure legends**



2

3 Figure 1. Differences in mm between PPD1 and PPD2 in healthy group, mucositis group 4 and total sample.

5 PPD1: periodontal probing depth with prosthesis in place; PPD2: periodontal probing

6 depth without prosthesis. Underestimation: PPD1<PPD2. Overestimation: PPD1>PPD2.

7



9

10 Figure 2. Scatter plot showing the differences between PPD1 and PPD2 for the total 11 sample and for the diagnosis subgroups (healthy and mucositis).

12 The dotted line represents total coincidence between PPD1 and PPD2 (supposing that the

13 values measured with and without prostheses were identical).

1	Appendices
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3 Supplementary Table 1. Distance between implant shoulder and mucosal margin, and 4 attachment level. 5 DIM: Distance between implant shoulder and mucosal margin; AL: attachment level 6 (PPD2 - DIM); PPD2: periodontal probing depth; 95% CI: 95% confidence interval. 7 8 Supplementary Table 2. Difference in mm between PPD1 and PPD2 in healthy implants 9 and implants with mucositis analysed by site. 10 PPD1: periodontal probing depth with prosthesis; PPD2: periodontal probing depth 11 without prosthesis. 12

13 **Supplementary Table 3.** Distance in mm between implant shoulder and mucosal

14 margin in healthy implants and implants with mucositis.

15 DIM: Distance between implant shoulder and mucosal margin.



16

17 **Supplementary Figure 1.** PPD2, DIM and AL without prosthesis.

18 PPD2: periodontal probing depth with prosthesis removed; DIM: Distance between

19 implant shoulder and mucosal margin; AL: Attachment level.

Appendices

- 3
- Supplementary Table 1. Distance between implant shoulder and mucosal margin, and 4

5 attachment level

	DIM		AL	
	Mean	95% CI	Mean	95% CI
Mesiobuccal	2.82	[3.23; 2.41]	1.73	[1.54; 1.92]
Buccal	2.27	[2.59; 1.96]	1.61	[1.484; 1.79]
Distobuccal	2.87	[3.30; 2.44]	1.55	[1.36; 1.74]
Mesiolingual	2.85	[3.25; 2.46]	1.58	[1.41; 1.76]
Lingual	2.85	[3.26; 2.45]	1.44	[1.28; 1.59]
Distolingual	3.10	[3.57; 2.62]	1.63	[1.42; 1.84]
Mean	2.80	[3.16; 2.43]	1.59	[1.45; 1.72]

DIM: Distance between implant shoulder and mucosal margin; AL: attachment level

6 7 8 9 (PPD2 - DIM); PPD2: periodontal probing depth without prosthesis; 95% CI: 95% confidence interval

- 1 Supplementary Table 2. Difference in mm between PPD1 and PPD2 in healthy implants
- 2 and implants with mucositis analysed by site
- 3

Probing difference (PPD1-PPD2)	Healthy n (%)	Mucositis n (%)	Total <i>n</i> (%)
2mm to 3mm	2 (8.0%)	9 (38.5%)	11 (8.0%)
(-1mm) to (+1mm)	74 (53.6%)	146 (62.4%)	220 (59.1%)
(-2mm) to (-3mm)	49 (35.5%)	66 (28.2%)	115 (30.9%)
(-4mm) to (-6 mm)	13 (9.4%)	12 (5.12%)	25 (6.7%)
< (-6mm)	0 (0%)	1 (0.4%)	1 (0.3%)
Total	138 (100%)	234 (100%)	372 (100%)

PPD1: periodontal probing depth with prosthesis; PPD2: periodontal probing depth without 4 5

prosthesis

1 Supplementary Table 3. Distance in mm between implant shoulder and mucosal

DIM	Healthy n (%)	Mucositis n (%)	Total <i>n</i> (%)
0 mm	12 (8.7%)	26 (11.1%)	38 (10.2%)
(-1mm) to (-3 mm)	74 (53.6%)	136 (58.1%)	210 (56.5%)
(-4mm) to (-6 mm)	51 (37.0%)	67 (28.6%)	118 (31.7%)
< (-6mm)	1 (0.7%)	5 (2.1%)	6 (1.6%)
Total transmucosal height	126 (91.3%)	208 (88.9%)	334 (89.8%)
Total	138 (100%)	234 (100%)	372 (100%)

2 margin in healthy implants and implants with mucositis

- 3 DIM: Distance between implant shoulder and mucosal margin
- 4