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Soft tissue contour changes at implant sites with or without soft tissue grafting in the esthetic zone: a retrospective case-control study with a 12-year follow-up

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Abstract

Objectives: to evaluate the volumetric changes and peri-implant health at implant sites with and without previous soft tissue grafting over a 12-year observation period.

Materials and methods: Eighteen patients received dental implants and simultaneous guided bone regeneration in the esthetic zone (15-25) for dental rehabilitation. Three months following implant placement, 8 patients (test) received an additional subepithelial connective tissue graft, whereas 10 patients (control) did not receive any additional ~~regenerative~~ treatment. One week after prothesis delivery and at the 5- and 12-years follow-up examination, impressions were taken. Obtained casts were processed for profilometric and linear analyses. The mean distance (MD) in the mid-buccal area between the two surfaces was considered the primary outcome. Peri-implant health was assessed based on clinical and radiographic data.

Results: Nine female and 7 male patients were re-assessed after a median follow-up time of 144.5 months (Min: 114.8; Max: 213.0). The median reduction of MD amounted to -0.81 mm (Min: -1.39; Max: 0.52) in the test group and -0.56 mm (Min: -0.93; Max: 0.11) in the control group, (intergroup comparison p=0.607, CI 95%: -0.760 / 0.530). None of the implants was diagnosed with peri-implantitis. Six test and 2 control implants were diagnosed with peri-implant mucositis (p=0.103).

Conclusions: Despite the limited number of included patients, similar results in terms of volumetric, linear changes and peri-implant conditions could be detected at implant sites with or without soft tissue grafting over a period of 12 years.

Introduction

Dental implants expanded treatment options in reconstructive dentistry with survival rates exceeding 90% at 5, 10 and 20 years of follow-up on the implant and restorative levels (Howe, Keys, & Richards, 2019; Jung, Zembic, Pjetursson, Zwahlen, & Thoma, 2012; Pjetursson, Thoma, Jung, Zwahlen, & Zembic, 2012; A. Roccuzzo et al., 2022). Key parameters assessing the long-term success of dental implants include biological (e.g. marginal bone levels, probing depth values, inflammatory parameters), technical and esthetic outcomes (French, Ofec, & Levin, 2021; Jung et al., 2012).

Owing to the trend of placing dental implants in a prosthetically-driven position, the need for regenerative procedures, on the hard and soft tissue level, increased over time (Benic & Hammerle, 2014). In a recent systematic review, the effect of guided bone regeneration on peri-implant health was evaluated. The outcomes of that review demonstrated that bone augmentation procedures can maintain peri-implant health and crestal bone levels over time (Sanz-Sanchez et al., 2018).

Recent scientific data also suggested that soft tissue grafting could be beneficial in maintaining peri-implant health (Buyukozdemir Askin et al., 2015; Cosyn et al., 2016; M. Roccuzzo, Grasso, & Dalmasso, 2016; Thoma et al., 2018). In addition, soft tissue augmentation procedures have been recommended to minimize marginal bone loss around dental implants (Linkevicius, Puisys, Linkeviciene, Peciuliene, & Schlee, 2015).

Clinical evidence on contour stability of subepithelial connective tissue grafts (SCTGs) around dental implants is to a great extent limited to observation periods of 5-years after insertion of final restorations (Bienz et al., 2017). Prospective studies are currently limited to 3-year follow-ups (De Bruyckere et al., 2020; De Bruyckere et al., 2018; Eeckhout, Bouckaert, Verleyen, De Bruyckere, & Cosyn, 2020; Rojo, Stroppa, Sanz-Martin, Gonzalez-Martin, & Nart, 2020; Thoma, Gasser, Jung, & Hämmerle, 2020). At the present time, the long-term (i.e. > 5-years) contour stability of dental implant sites having received a SCTG is unknown. This is mainly related to the fact that non-invasive methods to assess contour changes of implant

sites have only been introduced in the past 10 years (Eghbali, De Bruyn, Cosyn, Kerckaert, & Van Hoof, 2016; Schneider, Grunder, Ender, Hämmerle, & Jung, 2011).

Hence, the aim of the present study was to assess the profilometric (i.e. primary outcome) changes and peri-implant health (i.e. secondary outcomes) of implant sites treated with or without soft tissue grafting over a period of 12 years.

Materials and Methods

Study design

This study was designed as a case-control study. The study analyzes a particular pool of patients originally treated in a randomized controlled clinical trial, conducted at the Clinic of Reconstructive Dentistry, Center of Dental Medicine, University of Zurich, Switzerland (Gamper et al., 2017; Thoma, Sanz Martin, Benic, Roos, & Hammerle, 2014). After approval by the local ethics committee, patients received implant therapy between 2002 and 2005. The original study compared a one-piece and a two-piece implant system. From the study, all patients having received an implant in the esthetic zone (i.e. 15-25) were selected for a soft tissue contour analysis at 5 years following crown insertion (Bienz et al., 2017). Eighteen patients were eligible at 5 years. If patients had received more than one eligible implant for the study, one site was randomly selected. All implants had been placed with concomitant guided bone regeneration. Four to six weeks prior to abutment connection, 8 patients had received a SCTG (test), whereas no soft tissue augmentation procedures were performed in 10 patients (control). The decision to perform an additional soft tissue volume augmentation was based on esthetic indications, mainly including a volume deficit on the buccal side of the implant and depending on whether or not the patient agreed on the additional procedure. All 18 patients were recalled for a 5-year follow-up (Bienz et al. 2017). The same patients (and sites) were followed up in the present study. For the present 12-year analysis, 16 of the 18 originally included were available, 7 belonging to the test group and 9 belonging to the control group.

Surgical procedures

Details of the performed procedures have been previously reported in the 5-year data analysis (Bienz et al. 2017). Briefly, implant placement with simultaneous GBR procedures were performed at all 18 implant sites. GBR procedure was performed in all cases with Deproteinized Bovine Bone Mineral (DBBM) (Bio-Oss® Granules or Bio-Oss Collagen®;

Geistlich Pharma AG, Wolhusen, Switzerland) and a single layer collagen membrane (Bio-Gide®; Geistlich Pharma AG). Three to four months after implant placement, patients of the test group received a SCTG, and abutment connection was performed 4-6 weeks later. Abutment connection was performed 3-4 months after implant placement for the control group. The decision to perform an additional soft tissue augmentation procedure was based on biologic or esthetic reasons and patient acceptance to undergo an additional surgical intervention.

Clinical examinations

Follow-up examinations were performed one week after the insertion of the final restoration (baseline), at 5 years (5Y) and at 12 years (12Y). At every follow-up time-point, a thorough clinical examination was performed and periapical radiographs were taken. Moreover, alginate impressions of the implant sites were taken.

Processing of casts

Casts made of dental stone were examined meticulously for irregularities at the implant site. A desktop 3D scanner (Imetric 3D, Courgenay, Switzerland) was used to scan the casts, generating standard tessellation language (STL) files. The obtained STLs were imported into an image analysis software (Swissmeda Software, Swissmeda AG, Zurich, Switzerland). The baseline, the 5Y and the 12Y STL files were superimposed applying an automated algorithm of the software program, followed by manual adjustments.

Data evaluation

Contour analysis:

Two calibrated examiners independently performed all measurements on the superimposed STL files. For the 12Y analysis, the additional STL file was merged with the existing profilometric analysis and the measurement was repeated based on the region of interest

(ROI) that was selected for the 5Y analysis, thereby enabling consistency with the previous measurement. The ROI represented the esthetically critical area, as well as the area where the SCTG was placed (in case soft tissue augmentation was performed). The borders of the ROI were defined considering the references of the baseline scan. The coronal border was defined 1mm apical to the mucosal margin of the baseline situation, whereas the apical border was defined 5mm apically from the same point, but not exceeding the mucogingival junction. The locations of the mesial and distal borders varied between the sites, but were standardized to 1mm apart from the contact point of the adjacent teeth. The software calculated the area of the selected ROI, the volume between the surfaces and the mean distance between the surfaces at the different time-points (baseline, 5Y and 12Y). Since the volume is highly dependent on the size of the selected area, the data is expressed as mean distance between two surfaces (mm; MD).

Linear measurements:

A cross-section, representing the central implant axis, was selected to perform the linear measurements. The distance between the incisal edge of the baseline STL file to the buccal mucosal margin at baseline, 5Y and at 12Y were registered. The differences between the measurements/time-points represent the change of the buccal marginal mucosal level (mm; $bMML_{change}$). Ridge width changes at the buccal aspect of the implant were measured using the same cross-section at the different time-points. Measurements were performed horizontally at three levels below the buccal mucosal margin at baseline: 1mm (mm; $RW1_{change}$), 3mm (mm; $RW3_{change}$) and 5mm (mm; $RW5_{change}$).

Papilla index:

The papilla index (Jemt, 1997) was evaluated separately for the mesial (PI_{mesial}) and distal papilla (PI_{distal}) on the STL files, for each time-point. The following scoring system was considered: 0= no papilla present, 1= less than half of the height of the papilla present, 2= half or more of the papilla present, 3= papilla fills up the entire proximal space, 4= hyperplastic papilla.

Clinical:

Variables in terms of peri-implant health were recorded at the clinical examinations according to a previously described protocol (Thoma et al. 2014). The health of the peri-implant tissues was assessed by recordings of probing depth values (PD, mm), bleeding on probing (BOP, %) and plaque control record (PCR, %) at six sites per implant at baseline, at 5 years and at 12 years.

Radiographic:

Marginal bone levels (MBL) were assessed through two-dimensional x-ray analysis. For this purpose, intraoral radiographs were obtained at baseline, 5Y and at 12Y. The digitally obtained radiographs were transferred to a computer program (ImageJ, National Institutes of Health (NIH), Maryland, USA) to perform the measurements. For calibration purposes, the known thread pitch of the implants was used. Bone loss was calculated as the distance from the implant shoulder to the most coronal bone-to-implant contact on the mesial and distal side of the implant. An independent examiner performed all the radiographic measurements. Mean values were calculated for each implant. In addition, changes in MBL between time-points were calculated.

Peri-implant health:

Peri-implant health and diseases were assessed according to the consensus report of the World Workshop on the classification of periodontal and peri-implant diseases and conditions (Berglundh et al., 2018a, 2018b). More specifically, peri-implant health was characterized at the clinical level by the absence of signs of soft tissue inflammation, e.g. absence of bleeding on gentle probing (BOP) and suppuration (Araujo & Lindhe, 2018). Peri-implant mucositis was defined as presence of BOP and/or suppuration with or without increased probing depth compared to previous examinations in conjunction with the absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling (Heitz-Mayfield & Salvi, 2018). Peri-implantitis was defined by the presence of BOP and/or suppuration, increased probing depths compared to previous examinations and presence of bone loss beyond crestal

bone level changes resulting from initial bone remodeling (Schwarz, Derks, Monje, & Wang, 2018).

Statistical analysis

Data was recorded in a spreadsheet (Microsoft Excel, Microsoft Corporation, Redmond, Washington, USA) and statistical analysis was performed with a statistical analysis software (SAS 9.4, SAS Corp., Cary NC. USA). Descriptive summary statistics for numerical variables was obtained and intergroup comparison between the medians of the test and control group was performed by Wilcoxon-Mann-Whitney test. Categorical data were compared with the Chi-square test. The Hodges–Lehmann estimation of the differences between the groups and corresponding nonparametric confidence intervals were applied and presented in Appendix table 1. The level of significance was set at 5%. Corrections for the multiple testing was not applied since only one primary endpoint MD 12Y was considered.

Results

Nine female and 7 male patients with a median age of 67.9 years (Min: 34.0; Max: 87.3) at the 12-year follow-up completed the investigation with a median follow-up time of 144.5 months (Min: 114.8; Max: 213.0). Two patients were smokers over the entire observation period, both belonging to the control group. No complications were detected at any of the evaluated implant sites over the observation period. The differences between the two examiners are shown in Table 1. $bMML_{change}$ at 12 years was significantly different between the examiners (p=0.009; Min: -1.73; Max: 0.37). Table 2 provides the averaged data of the two examiners. Figures 1 to 3 depict clinical cases with considerable gain or loss from the test group as well as a clinical case of the control group with minimal changes over time.

Profilometric analysis and papilla index

The median loss of MD over the entire observation period amounted to -0.81 mm (Min: -1.39; Max: 0.52) in the test group and -0.56 (Min: -0.93; Max: 0.11) in the control group. The loss was not statistically significantly different between the groups (intergroup p=0.606; CI 95%: -0.76 / 0.53) (Table 2, Figure 4).

The variance of the values in the test group (n=7) increased at the 12Y follow-up, as there was one patient with a considerable gain (+0.5 mm, measured by both examiners), and three patients with a loss of more than 1 mm.

The data for bMML and RW are presented in Table 2. The change of bMML and $RW1_{change}$ followed a similar trend, without being statistically different between groups (p=0.408; p= 0.351). With respect to RW3 and RW5, the differences between groups as well as the changes from 5Y to 12Y were also not statistically significant (p>0.05).

All these changes from BL to 5Y and 12Y were within each group significantly different from 0 (p<0.05, without correction for the multiple testing), indicating a significant loss over time. Papilla index (PI) values did not change statistically significantly neither at the 5Y and 12Y follow-up examination within and between groups (p>0.05).

Peri-implant health and marginal bone levels

All clinical and radiographic changes are summarized in Table 3. None of the implants was diagnosed with peri-implantitis. At 5Y, 7 out of 9 implants (control, 77.8%) and 3 out of 6 implants (test, 50%) were diagnosed with a mucositis (p=0.580). At 12Y, 6 out of 7 implants (control, 85.7%) and 2 out of 6 implants (test, 33.3%) were diagnosed with peri-implant mucositis (p=0.103). The mean PCR scores ranged between 2.3% and 14.4% for both groups at all time-points without statistically significant differences (p>0.05).

At baseline, the mean marginal bone levels amounted to -0.40 mm (Min: -1.21; Max: 0.51) for the test and 0.01 mm (Min: -1.42; Max: 0.96) for the control group (intergroup p=0.470; CI 95%: -1.349 / 0.537) and -0.88 mm (Min: -2.58; Max: 0.52) for the test and -0.51 mm (Min: -1.44; Max: 0.68) for the control group (intergroup p=0.607; CI 95%: -1.595 / 0.760). Changes from baseline to 12y were not significant (test p=0.074, control p=0.109, intergroup p=0.837).

Discussion

The present retrospective case-control study assessed peri-implant soft and hard tissue stability in patients treated with or without SCTG after GBR procedures over an observation period of 12 years. The long-term results demonstrated changes in terms of (i) mean distance in the selected buccal ROI and (ii) vertical and horizontal soft tissue reduction without statistically significant differences between the groups. These findings were corroborated by correlations between volumetric and linear measurements. Moreover, soft tissue augmentation procedures at implant sites did not have any detrimental effects in terms peri-implant biologic response up to 12 years.

Despite the long-term clinical and radiographic outcomes assessing the reliability of GBR procedures concomitant to implant placement (Buser et al., 2013; Jung et al., 2021), nowadays no long-term data are available on soft tissue changes after soft tissue grafting procedures at implant sites. This is mainly related to the fact that historically, clinical research has focused on peri-implant hard tissue while only recently peri-implant soft tissue has gained popularity and has become a main focus for researchers (Thoma et al., 2021).

It is widely accepted that the use of a SCTG does represent the gold standard to augment peri-implant soft tissue in the esthetic zone (Jung et al., 2022): indeed, due to its morphological characteristics, this tissue does provide sufficient volume which remains stable in the long-term as shown within the present study, where a minimal shrinkage (i.e. <1mm) has been detected at test sites at the 12-year follow-up. Consequently, in light of the obtained results, the use of a SCTG, despite the reported increased patient's morbidity (Lorenzo, Garcia, Orsini, Martin, & Sanz, 2012; Sanz, Lorenzo, Aranda, Martin, & Orsini, 2009) should be recommended in cases of soft tissue grafting procedures in the esthetic zone.

With respect to PI changes over time, minimal changes both at mesial and distal papilla within the groups were detected. The 12-year data corroborated the 5-year analysis: in general, higher PI scores were detected at implant site adjacent to teeth rather than dental implants. These findings might be related to presence of an intact periodontal attachment at tooth sites which has been pointed out to be of paramount importance to ensure papilla fill (M. Roccuzzo, Roccuzzo, & Ramanuskaite, 2018; Tarnow et al., 2003). When focusing on potential correlation between peri-implant buccal soft tissue changes and changes of papilla height, no correlation was detected at the latest follow-up visit.

The assessment of the peri-implant conditions has revealed healthy peri-implant conditions around all implants characterized by physiological PD (i.e. < 5mm) and limited MBL changes (i.e. < 1mm) at 12-year follow-up evaluation. With respect to BOP scores, it has to be pointed out that they were exceeding 40% in both groups: these data are in accordance with previous publications which reported a slight increase of this clinical parameters through time (Monje et al., 2021). Nevertheless, it has to be underlined that anatomic and technical factors might lead to the clinical misinterpretation of bleeding after probing as a sign of trauma to the soft tissues instead of true mucosal inflammation (Hashim, Cionca, Combescure, & Mombelli, 2018). Despite the increasing level of evidence suggesting the beneficial role of peri-implant soft tissue thickening procedures to maintain peri-implant health (Tavelli et al., 2021), the present data is not revealing any differences between the groups. The authors speculate that the lack of difference might be related to the treated sites (i.e. maxillary anterior). The indication for a SCTG was given due to esthetic reasons rather than to correct thin soft tissues.

The present study does present some limitations which might be disclosed such as the retrospective design without a priori power analysis and the small sample size. Furthermore, patient reported outcome measures (PROMs) were not assessed. Future studies should assess PROMs, ideally during and after treatment and in respect to the expectations of the patient.

Consequently, the overall validity of the obtained data and their external validity is thereby limited.

Conclusion

Implant sites with and without soft tissue grafting on the buccal side revealed minimal changes over 12 years based on volumetric and linear outcome measures. There was a trend for more pronounced changes in the test group based on several parameters, but this was not statistically significant. This might be related to the small sample size, however, the confidence intervals indicated ranges which might not be clinically relevant. Periodontal parameters remained stable over time and the use of a SCTG based on an esthetic indication resulted in similar biological outcomes compared to non-grafted implant sites.

Author contributions

Conceptualization (R.J / D.T.); Methodology (S.B.); Software (S.B.); Data curation (S.B. / E.R.C. / J.H. / A.R.); Investigation (S.B. / E.R.C.); Validation (S.B.); Formal analysis (J.H. / A.R.); Supervision (S.B. / D.T.); Funding acquisition (R.J. / D.T.); Visualization (S.B. / J.H. / A.R.); Project administration (D.T.); Resources (R.J. / D.T.); Writing – original draft (S.B. / A.R.); Writing – review & editing (E.R.C / D.T. / R.J. / H.J.).

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Conflict of interest

The authors report no conflict of interest related to the study.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Figures

Figure 1

The test site 22 has lost more than 1mm (mean distance, MD) over 12 years. The clinical result could still be considered as acceptable. a = baseline situation; b = 12-year follow-up; c = representative cross-section of the profilometric analysis, baseline surface is yellow, 5-year surface is green and 12-year surface is grey

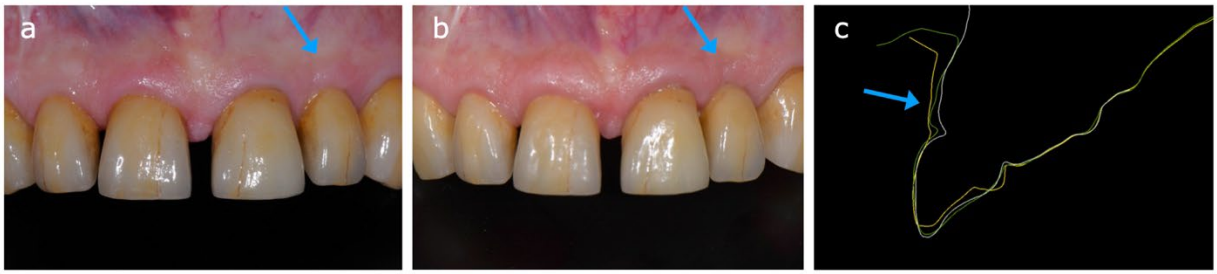


Figure 2

The test site 14 has gained 0.5 mm (mean distance, MD) over 12 years. The changes are clinically visible and occurred after 5 years, the implant is healthy and the marginal bone levels remained stable over time. a = baseline situation; b = 12-year follow-up; c = representative cross-section of the profilometric analysis, baseline surface is yellow, 5-year surface is green and 12-year surface is grey

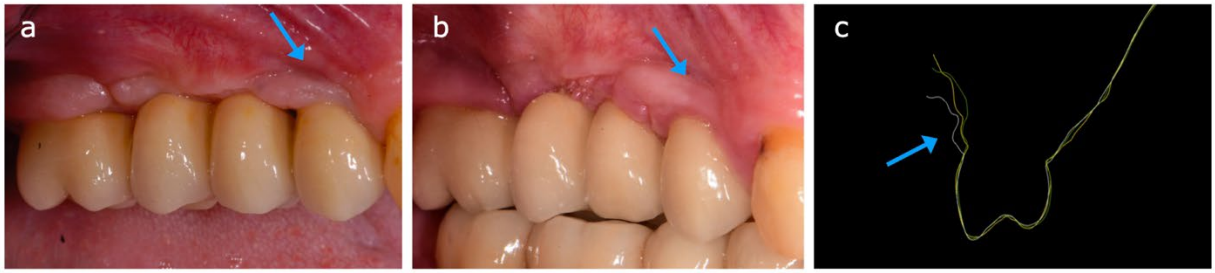


Figure 3

This control site (12) experienced minimal changes (mean distance, MD) over 12 years. a = baseline situation; b = 12-year follow-up; c = representative cross-section of the profilometric analysis, baseline surface is yellow, 5-year surface is green and 12-year surface is grey

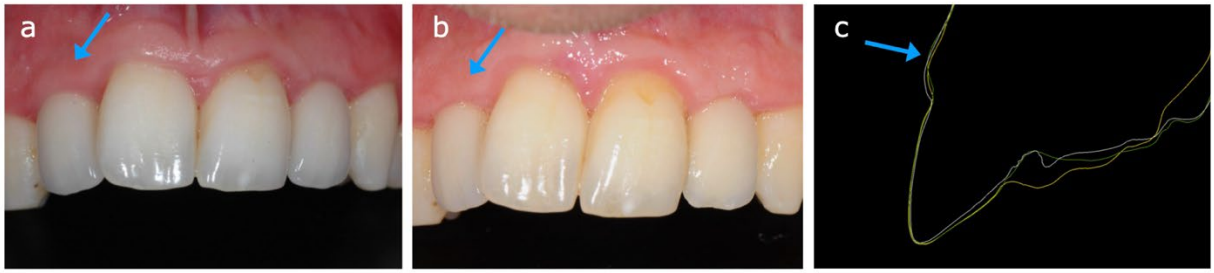
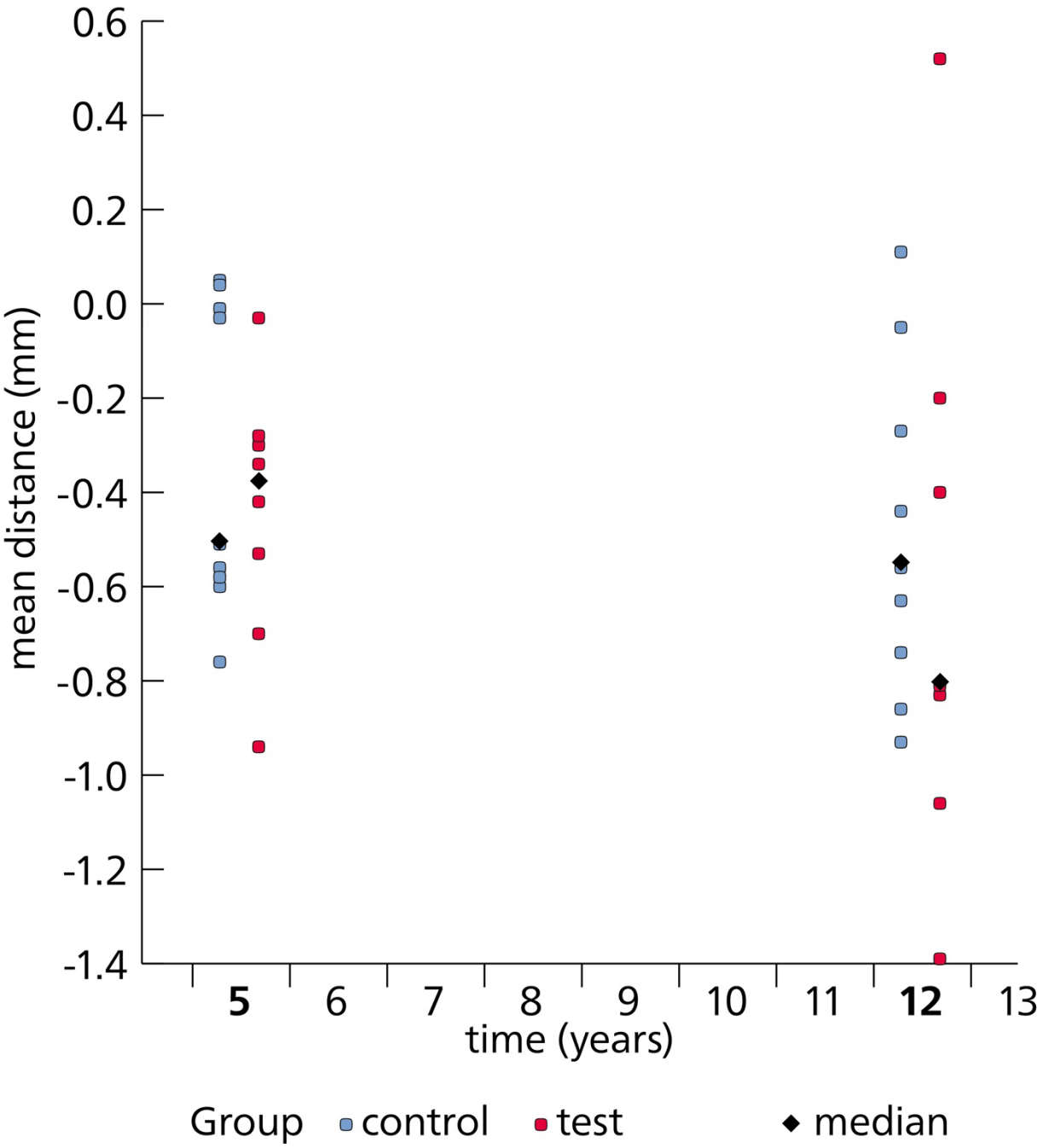


Figure 4

Scatterplot depicting the profilometric analysis (mean distance, MD) with the changes up to 5 years and up to 12 years.



Tables

Table 1 Results of the Wilcoxon signed rank test to compare the two examiners, based on the differences of the datasets. N = number, SD = standard deviation, Min = minimum, Q1 = 25% quartile, Q3 = 75% quartile, Max = maximum, PROB = probability (p-value), bMML = buccal marginal mucosal level, RW = ridge width, PI = papilla index.

Variable	N	Mean	SD	Min	Q1	Median	Q3	Max	PROB
Mean distance 5y	18	0.01	0.07	-0.14	-0.02	0.02	0.05	0.15	0.258
Mean distance 12y	16	-0.03	0.12	-0.37	-0.06	-0.02	0.01	0.22	0.131
PI_{mesial} baseline	18	-0.11	0.32	-1.00	0.00	0.00	0.00	0.00	0.500
PI_{distal} baseline	17	-0.24	0.44	-1.00	0.00	0.00	0.00	0.00	0.125
PI_{mesial} 5Y	18	-0.06	0.42	-1.00	0.00	0.00	0.00	1.00	1.000
PI_{distal} 5y	17	-0.12	0.33	-1.00	0.00	0.00	0.00	0.00	0.500
PI_{mesial} 12Y	16	-0.06	0.57	-1.00	0.00	0.00	0.00	1.00	1.000
PI_{distal} 12Y	15	0.20	0.68	-1.00	0.00	0.00	0.00	2.00	0.500
$bMML_{change}$ 5Y	18	-0.02	0.16	-0.42	-0.11	0.01	0.05	0.23	0.928
$bMML_{change}$ 12Y	16	-0.28	0.48	-1.73	-0.38	-0.18	-0.04	0.37	0.009
$RW1_{change}$ 5Y	18	-0.07	0.20	-0.56	-0.20	-0.08	0.04	0.25	0.123
$RW1_{change}$ 12Y	16	0.16	0.33	-0.50	0.01	0.12	0.29	0.76	0.043
$RW3_{change}$ 5Y	18	-0.02	0.07	-0.21	-0.03	0.00	0.01	0.07	0.552
$RW3_{change}$ 12Y	15	0.01	0.19	-0.28	-0.11	0.00	0.02	0.55	0.703
$RW5_{change}$ 5Y	15	0.02	0.16	-0.24	-0.04	0.02	0.06	0.39	0.531
$RW5_{change}$ 12Y	14	0.11	0.37	-0.40	-0.04	0.02	0.16	1.27	0.366

Table 2 Descriptive data of profilometric measurements and the papilla index, the means of both examiners are depicted. N = number, SD = standard deviation, Min = minimum, Q1 = 25% quartile, Q3 = 75% quartile, Max = maximum, bMML = buccal marginal mucosal level, RW = ridge width, PI = papilla index.

Group	Variable	N	Mean	SD	Min	Q1	Median	Q3	Max
control	Mean distance 0-5Y (mm)	10	-0.35	0.32	-0.76	-0.58	-0.51	-0.01	0.05
test	Mean distance 0-5Y (mm)	8	-0.44	0.28	-0.94	-0.61	-0.38	-0.29	-0.03
control	Mean distance 0-12Y (mm)	9	-0.48	0.36	-0.93	-0.74	-0.56	-0.27	0.11
test	Mean distance 0-12Y (mm)	7	-0.59	0.63	-1.39	-1.06	-0.81	-0.20	0.52
control	$bMML_{change}$ 0-5Y (mm)	10	-0.35	0.30	-1.02	-0.47	-0.33	-0.11	0.00
test	$bMML_{change}$ 0-5Y (mm)	8	-0.47	0.32	-1.10	-0.61	-0.42	-0.31	-0.01
control	$bMML_{change}$ 0-12Y (mm)	9	-0.47	0.40	-1.08	-0.66	-0.55	-0.12	0.06
test	$bMML_{change}$ 0-12Y (mm)	7	-0.53	0.78	-1.19	-1.04	-0.98	-0.12	1.00
control	$RW1_{change}$ 0-5Y (mm)	10	-0.52	0.44	-1.35	-0.70	-0.51	-0.17	0.00
test	$RW1_{change}$ 0-5Y (mm)	8	-0.62	0.45	-1.20	-0.91	-0.73	-0.36	0.22
control	$RW1_{change}$ 0-12Y (mm)	9	-0.67	0.45	-1.25	-1.11	-0.73	-0.30	-0.01
test	$RW1_{change}$ 0-12Y (mm)	7	-1.06	1.09	-2.77	-1.90	-0.99	-0.44	0.56
control	$RW3_{change}$ 0-5Y (mm)	10	-0.41	0.41	-1.10	-0.69	-0.54	0.00	0.19
test	$RW3_{change}$ 0-5Y (mm)	8	-0.50	0.20	-0.85	-0.62	-0.44	-0.38	-0.29
control	$RW3_{change}$ 0-12Y (mm)	9	-0.54	0.40	-1.32	-0.70	-0.42	-0.34	0.01
test	$RW3_{change}$ 0-12Y (mm)	6	-0.56	0.44	-1.33	-0.65	-0.54	-0.31	-0.01
control	$RW5_{change}$ 0-5Y (mm)	8	-0.52	0.52	-1.54	-0.74	-0.49	-0.16	0.12
test	$RW5_{change}$ 0-5Y (mm)	7	-0.60	0.42	-1.21	-1.05	-0.59	-0.34	0.00
control	$RW5_{change}$ 0-12Y (mm)	8	-0.68	0.57	-1.83	-0.94	-0.54	-0.31	-0.05
test	$RW5_{change}$ 0-12Y (mm)	6	-0.64	0.51	-1.37	-1.13	-0.46	-0.33	-0.08
control	PI_{mesial} baseline	10	1.85	0.67	1.00	1.00	2.00	2.00	3.00
control	PI_{distal} baseline	9	1.61	0.65	1.00	1.00	1.50	2.00	2.50
control	PI_{mesial} 5Y	10	1.70	0.63	1.00	1.00	2.00	2.00	2.50
control	PI_{distal} 5Y	9	1.39	0.78	0.00	1.00	1.00	2.00	2.50
control	PI_{mesial} 12Y	9	1.56	0.39	1.00	1.50	1.50	2.00	2.00
control	PI_{distal} 12Y	8	1.06	0.73	0.00	0.50	1.00	1.75	2.00
test	PI_{mesial} baseline	8	1.56	1.05	0.00	0.75	2.00	2.00	3.00
test	PI_{distal} baseline	8	1.56	1.24	0.00	0.25	2.00	2.50	3.00
test	PI_{mesial} 5Y	8	1.44	1.12	0.00	0.50	1.50	2.25	3.00
test	PI_{distal} 5Y	8	1.31	1.03	0.00	0.50	1.25	2.00	3.00
test	PI_{mesial} 12Y	7	1.64	1.11	0.00	1.00	1.50	3.00	3.00
test	PI_{distal} 12Y	7	1.71	0.95	0.00	1.00	2.00	2.00	3.00

Table 3 Descriptive data for all clinically evaluated variables and marginal bone levels. N = number, SD = standard deviation, Min = minimum, Q1 = 25% quartile, Q3 = 75% quartile, Max = maximum, PCR = plaque control record, PD = probing depth, BOP = bleeding on probing, MBL = marginal bone level.

Group	Variable	N	Mean	SD	Min	Q1	Median	Q3	Max
control	PCR baseline (%)	10	14.10	23.90	0.00	0.00	0.00	25.00	75.00
test	PCR baseline (%)	6	8.30	20.40	0.00	0.00	0.00	12.50	50.00
control	PCR 5Y (%)	10	14.40	16.70	0.00	0.00	12.50	26.60	50.00
test	PCR 5Y (%)	6	9.70	15.30	0.00	0.00	0.00	27.10	33.30
control	PCR 12Y (%)	7	2.30	3.90	0.00	0.00	0.00	8.00	8.00
test	PCR 12Y (%)	6	7.00	11.10	0.00	0.00	0.00	19.00	25.00
control	PD baseline (mm)	10	2.76	0.92	1.50	2.23	2.75	3.00	5.00
test	PD baseline (mm)	7	3.45	0.66	2.80	3.00	3.20	3.67	4.80
control	PD 5Y (mm)	10	3.65	1.38	2.00	2.92	3.33	4.00	6.67
test	PD 5Y (mm)	7	3.67	0.79	2.67	3.00	3.67	4.33	5.00
control	PD 12Y (mm)	7	3.45	1.03	2.08	2.50	3.38	4.17	5.17
test	PD 12Y (mm)	6	3.50	0.92	2.00	2.88	3.53	4.19	4.75
control	BOP baseline (%)	10	35.30	30.50	0.00	0.00	37.50	57.60	87.50
test	BOP baseline (%)	7	34.90	29.60	0.00	16.00	25.00	75.00	75.00
control	BOP 5Y (%)	10	37.50	28.90	0.00	18.80	31.30	75.00	75.00
test	BOP 5Y (%)	7	37.70	26.30	12.50	12.50	31.30	66.70	75.00
control	BOP 12Y (%)	7	44.00	25.00	0.00	33.00	50.00	67.00	75.00
test	BOP 12Y (%)	6	45.80	32.60	16.00	16.50	37.50	75.30	100.00
control	MBL baseline (mm)	9	0.01	0.67	-1.42	-0.28	0.00	0.49	0.96
test	MBL baseline (mm)	7	-0.40	0.81	-1.21	-1.18	-0.72	0.50	0.51
control	MBL 5Y (mm)	9	-0.19	0.80	-1.46	-0.76	-0.27	0.55	1.01
test	MBL 5Y (mm)	7	-0.50	1.13	-2.16	-1.50	-0.32	0.52	0.93
control	MBL 12Y (mm)	9	-0.51	0.64	-1.44	-0.92	-0.62	-0.01	0.68
test	MBL 12Y (mm)	7	-0.88	1.10	-2.58	-1.98	-0.68	0.01	0.52

Appendix table 1 Hodges-Lehmann estimation of the differences between the groups and corresponding nonparametric confidence intervals (95% CI). bMML = buccal marginal mucosal level, RW = ridge width, PI = papilla index, PCR = plaque control record, PD = probing depth, BOP = bleeding on probing, MBL = marginal bone level.

Variable	HLest	lower_cl 95%	upper_cl 95%
Age at 12Y	-2.984	-25.214	14.896
Mean distance 5Y	-0.065	-0.410	0.260
Mean distance 12Y	-0.175	-0.760	0.530
$bMML_{change}$ 5Y	-0.128	-0.440	0.160
$bMML_{change}$ 12Y	-0.240	-0.875	0.700
$RW1_{change}$ 5Y	-0.163	-0.650	0.390
$RW1_{change}$ 12Y	-0.265	-1.525	0.735
$RW3_{change}$ 5Y	-0.108	-0.435	0.270
$RW3_{change}$ 12Y	-0.010	-0.490	0.415
$RW5_{change}$ 5Y	-0.080	-0.660	0.425
$RW5_{change}$ 12Y	0.018	-0.760	0.700
PI mesial baseline	0.000	-1.000	1.000
PI distal baseline	0.000	-1.000	1.000
PI mesial 5Y	0.000	-1.000	1.000
PI distal 5y	0.000	-1.000	1.000
PI mesial 12Y	0.000	-1.000	1.000
PI distal 12Y	1.000	0.000	1.500
PCR baseline	0.000	-0.250	0.000
PCR 5Y	0.000	-0.250	0.125
PCR 12Y	0.000	0.000	0.170
PD baseline	0.700	0.200	1.500
PD 5Y	0.333	-0.667	1.167
PD 12Y	0.025	-1.380	1.370
BOP baseline	0.000	-0.340	0.250
BOP 5Y	-0.031	-0.250	0.313
BOP 12Y	-0.040	-0.340	0.420
MBL baseline	-0.490	-1.349	0.537
MBL 5Y	-0.246	-1.585	1.000
MBL 12Y	-0.216	-1.595	0.760
$RW3_{change}$ 12Y	-0.010	-0.490	0.415
$RW5_{change}$ 5Y	-0.080	-0.660	0.425
$RW5_{change}$ 12Y	0.018	-0.760	0.700

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