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A pilot study on the association between soft tissue volumetric changes and non-surgical periodontal treatment in stage III periodontitis patients. A case series study

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ABSTRACT

Objectives: This study investigates the correlation between soft tissue volumetric changes and clinical periodontal parameters for patients suffering from Stage III periodontitis after non-surgical periodontal treatment (NSPT) via intraoral scanning.

Methodology: The following study is a case series pilot study involving twenty-eight Stage III Periodontitis patients. All subjects received full-mouth periodontal examination and intra-oral scanning cat baseline and re-evaluation. NSPT with bi-weekly oral hygiene reviews were carried out, and re-evaluation was performed after 10–12 weeks. Baseline scanned data of all subjects would be superimposed with the corresponding scanned data obtained during re-evaluation to ensure the teeth are in the correct alignment. Boolean subtraction would be performed with the 3D scanned data after superimposition and transformation into a 3D solid. The association of baseline clinical parameters and changes after NSPT with soft tissue volumetric changes up to tooth surface level would be evaluated.

Results and conclusion: Mean volumetric reduction after NSPT was 153.45 $mm^3 \pm 185.30\ mm^3$ and 124.06 $mm^3 \pm 124.17\ mm^3$ for the maxillary and mandibular arch, respectively. A statistically significant correlation was detected between soft tissue volumetric reduction to baseline and post-treatment clinical periodontal parameters. Posterior teeth were found to have the highest reduction in soft tissue volume.

According to this pilot study, baseline clinical periodontal parameters (PPD, CAL, BOP) correlate with the soft tissue volumetric reduction after NSPT. Further studies on a larger scale and utilization of digital means on tooth sites would be necessary to strengthen the proof of concept.

Clinical significance: Intraoral scanning can be a valid non-invasive method to assess soft tissue volumetric changes after initial periodontal treatment, which are correlated to changes in the baseline clinical periodontal parameters.

1. Introduction

Periodontitis is characterized by the progressive destruction of the tooth-supporting apparatus [1]. Accumulation of dental biofilms consequent to inadequate self-performed oral hygiene procedures commences a cascade of a biological process that, together with the unique susceptibility profile of each individual and may lead to microbial dysbiosis, initiating and sustaining the inflammatory disease process that ultimately leads to periodontal destruction and tooth loss [2]. From the therapeutic standpoint, according to the latest clinical guidelines for managing patients with periodontitis [3], the recommendation is a staged approach with the initial phase of the treatment directed

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towards changes in the motivation and behaviour of patients. The second step of periodontal treatment consists of non-surgical means to control the subgingival infection. The treatment aims to resolve inflammation with a reduction in tissue oedema. The mean increase in gingival recession was reported between 1.3 mm to 1.6 mm after NSPT [4]. Regarding the resolution or reduction of Probing Pocket Depth (PPD), significant improvements can be expected in sites with 5–6 mm initial PPD.

In contrast, areas with PPD >6 mm rarely return to physiologic levels without further surgical intervention [5]. Bleeding on probing (BOP) is expected to be reduced upon the resolution of gingival inflammation [6]. BOP is an essential parameter due to its high negative predictive value when it comes to disease progression [7]. It was found that the ratio between volume densities of infiltrated and non-infiltrated connective tissue was higher at sites with BOP than those that did not. [8] Strong agreement up to 85.4% has been identified for the detection of BOP for sites with PPD≥4 mm [9].

A novel noninvasive approach could be an alternative since technological advances with intraoral 3D laser scanning make the assessment of changes in tissue volume feasible, practical and precise, eliminating intermediate steps that could lead to distortion and reducing the invasiveness of the evaluation. Initially, intraoral scanning was utilized in restorative prostheses fabrication, for instance, the inlays, short-span bridges, and other CAD-CAM restorations [10]. Nowadays is a standard tool in prosthetic and implant dentistry [11] as well as in diagnosis and treatment planning in orthodontics [12]. It has been shown that it could be a possible tool to monitor tooth wear for patients [13,14]. Until recently, few attempts have been made to quantify changes in oedema directly to detect volumetric changes [15]. Three-dimensional volumetric assessment has been used in a previous study assessing changes after soft tissue grafting procedures [16]. Another study investigated subjects with drug-induced gingival overgrowth [17], where they compared the scanned model before and after gingivectomy procedures. It was reported that the measurement of gingival thickness changes would be accurate to 60 µm. Regarding methodology, another recent study used conventional impressions from the patient first and then performed intra-oral scanning before they compared the changes digitally [18]. In addition, for the data analysis, current studies generally consider the change in soft tissue volume on a full arch basis instead of on a tooth-by-tooth or tooth-surface basis [19].

Finally, this technology may improve communication between patients and operators [20].

The primary aims of this study were: (i) the evaluation of the reliability of quantitatively assessing treatment responses after NSPT through intraoral scanning and volumetric 3D processing; (ii) the identification of the factors affecting changes in gingival volume after NSPT; and (iii) the testing of the strength and significance of the correlation between outcomes evaluated by conventional periodontal probing and 3D imaging. In summary, we hypothesized that the treatment response after NSPT, except measurements of traditional periodontal clinical parameters, could be assessed and correlated volumetrically with a non-invasive procedure since this could reflect the resolution of inflammatory oedema and improvement of the gingival tone of the periodontal tissues. On a more clinical/practical approach, we are interested to assess the use of I/O scanning to quantify volumetric changes of the periodontal soft tissues that follow the initial treatment.

2. Materials and methods

2.1. Study design

This case series investigates the association between soft tissue volumetric changes and clinical parameters before and after NSPT. The study was conducted in the Prince Philip Dental Hospital Hong Kong (PPDH) between October 2020 and June 2021. All participants were 18 years of age or above and enroled through the Reception and Primary Care of PPDH.

2.2. Inclusion and exclusion criteria

The inclusion criteria were:

(1) >18 years old
(2) Subjects with Stage III periodontitis with reference to the criteria proposed in the 2017 EFP World Workshop
(3) Dentate with at least 20 teeth.

The exclusion criteria were:

(1) Pregnant females,
(2) Presence of any systemic disease that can alter the manifestation/outcome of periodontal treatment,
(3) Subjects who have received antibiotic medication within the previous three months before baseline examination,
(4) Subjects who have received periodontal treatment in the last 12 months.

2.3. Sample size and ethical approval

The sample size was based on recommended pilot study sample sizes (Birkett & Day, 1994), where a sample size of 28 has 80% power to detect a correlation differing from zero with an expected moderate correlation coefficient of 0.5 [21], at the 0.05 significance level. Twenty-eight subjects have been included in this case series. The study protocol was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (IRB Approval Number: UW20–714). All procedures included in this study were conducted in accordance with the current revision of the Declaration of Helsinki. Written consent was obtained from all subjects prior to the commencement of the study.

2.4. Clinical examination and non-surgical periodontal treatment

All subjects received a full mouth periodontal examination performed by a single calibrated examiner (ML). Periodontal examination was conducted at baseline and re-evaluation. Probing pocket depth (PPD), bleeding on probing (BOP), recession (REC) and clinical attachment level (CAL) are clinical periodontal parameters that were recorded with a periodontal probe (UNC-15, Hu-Friedy) at six sites per tooth.

Clinical parameters were assessed on five patients against an experienced periodontist (MF) for calibration purposes. All subjects were diagnosed using the 2017 classification by EFP [22]. The diagnosis was assisted with an orthopantomogram and long cone periapical radiographs. According to the latest classification, smoking and diabetic status were considered grade modifiers. The extent of the disease would be classified as localized or generalized by the threshold of 30% of all dentitions. Health condition data were collected with the use of a questionnaire.

Subjects received NSPT by quadrant or half-mouth approach in six to eight appointments with bi-weekly oral hygiene review by the same trained operator (AK). No adjunctive antibiotics or mouthrinse were prescribed to the subjects. *Re*-evaluation was conducted 10–12 weeks postoperatively (Appendix Fig. 1).

2.5. Intraoral scanning

All subjects received intra-oral scanning with 3Shape TRIOS® intraoral scanner at baseline (T0) and re-evaluation (T1) by the same operator (ML). In addition, calibration in relation to repeatability was performed on 5 patients against the same experienced periodontist (MF) was conducted before the data collection process. Intraoral scanning data were in the form of mesh and were exported as STL files. The intraoral scans were obtained with a standardized one-scan zigzag occlusal-oral-buccal scanning strategy. Intraoral scans were imported to an image analysis software program (Geomagic Control X, 3D Systems, Rock Hill, SC, USA) where image pairs were superimposed using 3D surface comparison function according to an area-designated best-fit algorithm [23]. The global surface deviation values of teeth surfaces on compared images were below 150 μm with favourable distribution patterns of surface deviation using visual inspection of colour mapping.

2.6. Digital assessment of soft tissue volumetric changes

The baseline scanned data of all subjects would be superimposed with the corresponding scanned data obtained during re-evaluation to ensure the teeth are in the correct alignment. The superimposition was performed with the Blue Sky Plan software (Blue Sky Plan Version 4.8.3, Blue Sky Bio® LLC Grayslake, IL, USA). Different views of the tooth alignment would be checked after auto-alignment performed by the software, and manual adjustment would be implemented if necessary.

The 3D intra-oral scanning data was in the form of mesh upon exportation from the scanner. 3D solids were created to facilitate the subsequent volumetric analysis (Fig. 1). The transformation was also performed with the Blue Sky plan software (Blue Sky Plan Version 4.8.3, Blue Sky Bio® LLC Grayslake, IL, USA).

Boolean subtraction is based on the subtraction of two 3Dsolids (Fig. 2). This would be performed with the 3D scanned data after superimposition and transformation into a 3D solid. Materialize Magics ® (Leuven, Belgium) would be used to execute the subtraction function of the Boolean operation. The Boolean operation function in Materialized Magics software was applied to subtract the aligned post-treatment solid model from the baseline solid model to create a new part which could be quantified.

This could enable the volumetric changes to be quantified and expressed in cubic millimetres (mm^3).

Results from Boolean subtraction would further be divided into a tooth-by-tooth basis with Materialise Magics ® (Leuven, Belgium). 3D Scanned data from each subject at baseline would be used as a reference and overlapped with the Boolean subtraction data. The contact point was chosen to be the area to divide the data on a tooth-by-tooth basis.

A high degree of reliability was found between the repeated tooth-by-tooth volumetric differences in measurements performed on 10 randomly selected jaws. The average measure interclass correlation coefficient (ICC) was 0.96 with a 95% confidence interval from 0.95 to 0.97 ($F(278,278) = 23.03$, $p < 0.001$).

2.7. Statistical analysis

Twenty-eight subjects have received periodontal examination and intraoral scanning at baseline (T0) and re-evaluation (T1). Descriptive statistics were reported on the age, gender, and grading of the periodontal disease (Table 1). For the convenience of statistical analysis, the clinical parameters were considered on a surface basis (buccal, palatal or lingual) for each tooth. Data were organized after the data collection by examining six sites per tooth. Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to evaluate the data normality. A paired T-test was implemented to test for the significance of changes in clinical periodontal parameters between baseline and re-evaluation (Appendix Table **S1**). Generalized estimating equations were used to investigate the possible correlation between the factors of interest, including location (anterior or posterior), baseline periodontal clinical parameters in groups (PPD, CAL and BOP), changes in those periodontal clinical parameters after NSPT and the ranked volumetric reduction for each tooth surface (Table 2). Spearman rank test was used to test the correlation on an arch basis for the changes in clinical parameters and volumetric reduction (Table 3). In order to reduce the possible error in data analysis due to the limitation of the Boolean subtraction method used in this study, sites with non-responsive periodontal pockets (13sites) presented with increased probing pocket depth after NSPT displayed no volumetric change after Boolean subtraction where still analysed but with values adjusted to zero mm PPD change at that site, and with corresponding volumetric analysis for those surfaces still being processed.

3. Results

3.1. Subject characteristics

All subjects were enroled with convenience sampling at PPDH from June 2020 to March 2021, with a mean age of 51 years old (range 27–75, 57.1% Female, 42.9% Male). Subjects were diagnosed to have Stage III

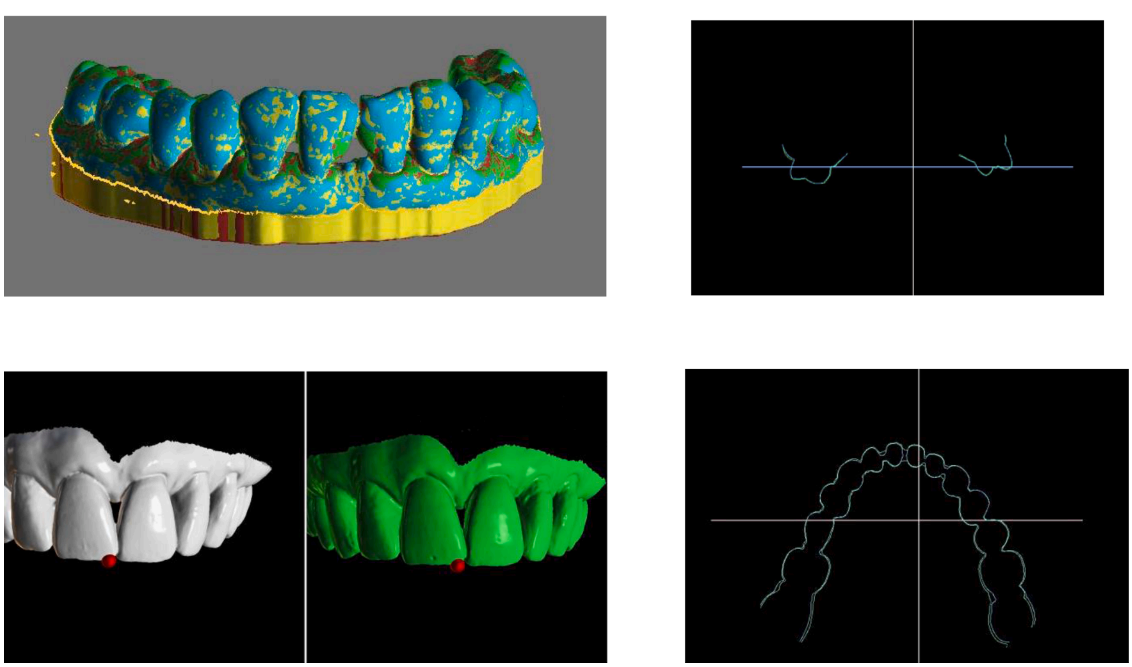

Fig. 1. Superimposition of scanned data with Blue Sky Plan.

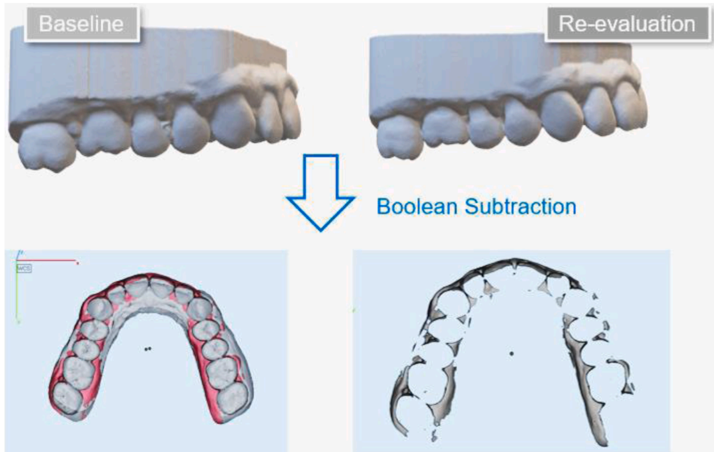

Fig. 2. Boolean operation (Subtraction) of the 3D solids (Baseline and re-evaluation)
Boolean subtraction performed with the 3D scanned data after registration and transforming from shell to part in Materialise Magics Software.

Table 1
Age, gender and periodontitis grading of subjects. .

		Mean	Std. Deviation	S.E. Mean
Age	$n = 28$	51.36	15.877	3.001
Gender		Percent	Valid Percent	Cumulative Percent
Male	$n = 12$	42.9	42.9	42.9
Female	$n = 16$	57.1	57.1	100
Stage III Grade		Percent	Valid Percent	Cumulative Percent
B (Generalize)	$n = 2$	53.6	53.6	53.6
B (Localized)	$n = 13$			
C (Generalized)_	$n = 7$	46.4	46.4	100
C (Localized)	$n = 6$			

Table 2
Generalized Estimating Equations model for significant factors related to volumetric reduction.

Factors affecting the observed volumetric changes in Generalized Estimating Equations model				
Parameter	Volume reduction (mm^3)			
	Mean (SD)	**Median**	**P-value**	**Bonferroni's Multiple Comparison**
Tooth Position				
(1) Anterior	3.23(6.48)	0.79	<0.001	(1) < (2)
(2) Posterior	6.5(10.49)	2.43		
Baseline PPD				
(1) Baseline PPD ≤3mm	2.12(4.58)	0.72	<0.001	(1) < (2) < (3)
(2) Baseline PPD 4–5mm	6.73(8.29)	3.58		
(3) Baseline PPD ≥6mm	16.44 (15.44)	11.67		
Baseline CAL				
(1) Baseline CAL ≤3mm	1.91(3.75)	0.65	<0.001	(1) < (2), (3)
(2) Baseline CAL 4–5mm	5.11(7.82)	1.92		
(3) Baseline CAL ≥6mm	12.76 (14.74)	7.45		
Baseline BOP				
(1) No BOP at baseline	1.08(1.83)	0.31	<0.001	(1) < (2)
(2) BOP at baseline	5.98(9.84)	1.97		
PPD Reduction	5.10(9.14)	1.39	<0.001	

SD, standard deviation.
Intraclass Correlation within person: 0.220.

Table 3
Non-parametric test-Spearman Correlation for changes in clinical parameters after NSPT with volumetric reduction.

	Spearman Correlation Coefficient	p-value
PPD Reduction		
Upper	0.658**	<0.001
Lower	0.636**	<0.001
Full mouth	0.739**	<0.001
CAL Change		
Upper	0.511**	0.005
Lower	0.410*	0.03
Full mouth	0.493**	0.008
BOP no. of sites reduction		
Upper	0.570**	0.002
Lower	0.560**	0.002
Full mouth	0.495**	0.007

* Significant at 0.05 level.
** Significant at 0.01 level.

periodontitis according to the criteria proposed in the 2017 EFP World Workshop. 53.6% of the subjects presented with Grade B periodontitis, while there were 46.4% found to have grade C periodontitis (Table 1). Amongst the twenty-eight subjects, one of them presented with well-controlled diabetes, and none of the recruited subjects reported having a smoking habit.

3.2. Baseline clinical parameters

Baseline clinical data were organized and divided into three groups for PPD and CAL according to the magnitude in ascending order. The site presented with the deepest pocket or greatest clinical attachment level amongst the three sites of each tooth surface would be considered for the grouping. The three groups were (1) less than or equal to 3 mm (2) 4–5 mm (3) more than or equal to 6 mm. It was found that majority of the surfaces (62.6%) have baseline probing pocket depth less than or equal to 3 mm, whereas 13% of the surfaces have pockets greater than or equal to 6 mm. The mean baseline PPD of the total buccal/lingual surface was identified to be 8.46 mm±3.29 mm. (Appendix Table S2) The “mean baseline PPD of the total buccal/lingual surface” value is a processed data, and it is computed as the mean sum of PPD values at 3 sites (the mesial-buccal, mid-buccal and distal-buccal OR mesial-lingual, mid-lingual and distal-lingual) for the buccal/lingual surface. This was also applied to CAL computations. In other words, the mean PPD/CAL values are at tooth surface level where the tooth was split buccal lingually to match with volumetric analysis on buccal/lingual surfaces of teeth.

For CAL, most of the sites presented with clinical attachment level less than or equal to 5 mm, 18.0% were found to have CAL greater than or equal to 6 mm according to the baseline periodontal examination results. It was found that the mean CAL was 10.08mm± 4.29 mm. Concerning BOP at baseline, any of the 3 sites of each tooth surface, either buccal, palatal, or lingual, with BOP detected would be considered as having a positive BOP result of that surface. A large proportion of surfaces (82.4%) was identified to have bleeding after probing with a periodontal probe, with a mean number of 1.79±1.10 of sites presented with BOP at baseline. (Appendix Table S2)

3.3. Changes in clinical parameters after NSPT

Reduction in PPD was detected after NSPT, the mean PPD reduction was found to be 1.57 mm±2.21 mm for each tooth surface. A small number of sites presented with increase in PPD at re-evaluation. The reduction in PPD after NSPT was found to be statistically significant. ($p < 0.001$)

The sum of CAL at baseline (T0) was compared with that of re-evaluation (T1). The mean CAL reduction was 1.29 mm±2.70 mm for each tooth surface and statistically significant difference in CAL was identified. ($p < 0.001$) The mean number of BOP site reduction was found to be 0.93±1.10 sites for each tooth surface. (Appendix Tables S1, S3)

3.4. Soft tissue volumetric changes

Volumetric data were obtained from each subject at baseline (T0) and at re-evaluation (T1) with the use of intra-oral scanner. The data were exported as STL files, after alignment and registration of the scanned data, Boolean subtraction would be performed and further divided into tooth-by-tooth basis with Materialise Magics ® (Leuven, Belgium). The volumetric difference between the baseline soft tissue condition and at re-evaluation would be considered on tooth surface basis (buccal, palatal/ lingual), arch basis (maxilla and mandible) and full arch. So here the volumetric analysis was performed on 2 surfaces per tooth (buccal and oral) with PPD pocket probing depth being computed as the sum of 3 sites (i.e. MB, Mid-B, DB) and correlated to the corresponding surface volumetric change values. A high degree of reliability was found between the repeated tooth-by-tooth volumetric differences in measurements performed on 10 randomly selected jaws. The average measure interclass correlation coefficient (ICC) was 0.96 with a 95% confidence interval from 0.95 to 0.97 ($F(278,278)=23.03$, $p < 0.001$). The mean volumetric changes for the maxillary arch was 153.45 $mm^3 \pm 185.30\ mm^3$ while for the mandibular arch was 124.06 $mm^3 \pm$ 124.17 mm^3 . When considering both maxillary and mandibular arch, the mean volumetric change was 277.70 mm^3 $\pm$301.63 mm^3. Details of volumetric changes per arch were listed (Appendix Table S4). The soft tissue volumetric changes results did not follow a normal distribution with Kolmogorov-Smirnov and Shapiro-Wilk tests for both maxillary and mandibular arches. (Appendix Table S5)

The anterior teeth were compared with the posterior teeth for their relationship with soft tissue volumetric changes. There were 42.2% of anterior surfaces and 57.8% of posterior surfaces. As the volumetric changes data did not follow a normal distribution, the data were transformed into rank for further analysis using the Generalized Estimating Equations model (GEEM). Statistically a significant relationship between the location in terms of anterior and posterior, in relation to the ranked volumetric changes was identified ($p < 0.001$).

GEEM was also applied for the baseline PPD, CAL in groups and the presence or absence of BOP at baseline. For all three parameters, a statistically significant correlation was identified in relation to the ranked volumetric reduction. ($p < 0.001$) (Table 4)

Ranked volumetric reduction was used in generalized estimating equations, the PPD reduction, CAL changes and the difference in number of sites with BOP after NSPT were applied to find the correlation with volumetric, reduction, respectively. There was statistical significance for the three factors, respectively. For PPD reduction and reduction in number of sites with BOP, the p-value was <0.001, while for CAL changes, $p = 0.003$ (Table 4).

Table 4
Generalized Estimating Equations model for location, baseline PPD, CAL, BOP & PPD, CAL, BOP reduction.

Source	Type III Wald Chi-Square	df	Sig.
(Intercept)	255.072	1	0.000
Anterior Posterior*	27.521	1	0.000
(Intercept)	680.261	1	0.000
T0 PPD in groups	88.151	2	0.000
(Intercept)	384.03	1	0.000
T0 CAL in groups	101.834	2	0.000
(Intercept)	282.572	1	0.000
T0 BOP	71.842	1	0.000
(Intercept)	295.451	1	0.000
PPD reduction	59.324	1	0.000
(Intercept)	320.672	1	0.000
CAL reduction	9.025	1	0.003
(Intercept)	258.411	1	0.000
BOP reduction	29.199	1	0.000

Changes in clinical parameters after NSPT was considered on arch basis, which is divided into maxilla and mandible, with the addition of volumetric reduction of the tooth surfaces involved, excluding edentulous area. The correlation with volumetric reduction was found to be statistically significant with Spearman's rank test for PPD reduction ($r = 0.658, 0.636$, $p < 0.001$), CAL changes ($r = 0.511,0.410$, $p < 0.05$) and reduction in number of sites with BOP ($r = 0.570,0.560$, $p = 0.002$). (Table 3) Finally when all factors involved were put together in the GEEM, the reduction of number of sites with BOP was found to be not significant ($p = 0.126$). After removing this from the model, the GEEM identified CAL changes to be not statistically significant as well. ($p = 0.099$) so CAL reduction was eliminated from the model and further analysis was performed. All the remaining factors were found to be statistically significant for the final model, including location (anterior or posterior), baseline PPD and CAL in groups, BOP at baseline and PPD reduction after NSPT ($p < 0.001$). The intraclass correlation coefficient was found to be 0.220 (Table 2).

4. Discussion

This study included 28 patients with stage III periodontitis, with most tooth surfaces presenting signs of gingival inflammation in the form of BOP up to 82.4% at baseline. The outcome after NSPT was satisfactory, with statistically significant improvement in all related parameters [5,24].

The outcomes were reevaluated 10-12 weeks after since no additional gain in clinical attachment is expected after three months [25]. In a recent study with an intra-oral scanning method to assess gingival inflammation, the scanning was performed two weeks after the NSPT, during which the tissue remodelling is ongoing [18].

Concerning the type of scanner used, a study looked on the use of different intraoral scanners and showed no statistically significant difference detected between the commonly used intra-oral scanners, including Primescan, Trios, iTero and Omnicam [26]. In addition, the accuracy of the 3Shape TRIOS® intra-oral scanner has been previously reported (Michelinakis et al. [27]) in periodontitis patients. Therefore, we have chosen to use Trios intra-oral scanner in this study and all scanning procedures were performed by the same operator (ML) to reduce inconsistency.

Regarding the methodology, in model superimposition, most recent studies would use Geomagic or GOM software [15,18] for the model alignment process. Our study considered using open-source dental-related software, the Blue Sky Plan (Blue Sky Plan Version 4.8.3, Blue Sky Bio® LLC Grayslake, IL, USA). Different studies have demonstrated that

Blue Sky Plan's accuracy is comparable to other commonly used implant planning software, including Geomagic Design X. [28]. The software automatically performed best-fit alignment with manual adjustment if necessary. This method was found to be easier to manipulate. Models were superimposed regarding the tooth alignment, which was assumed to be at a stable position.

For the association of soft tissue volumetric changes at the arch level, non-parametric tests have been performed for PPD reduction (Table 3). Moderate correlation has been demonstrated, and the results were comparable to the previous study [18].

Tooth location showed a statistically significant correlation with the volumetric changes in our study. It was found that posterior teeth would have relatively more soft tissue volumetric changes after non-surgical periodontal treatment.

Correlation has also been investigated between baseline clinical parameters, including PPD, CAL and BOP, in relation to the soft tissue volumetric changes. These three factors demonstrated a statistically significant relationship with volumetric reduction when evaluating the factor individually and after considering all the seven factors involved in the GEM. ($p < 0.001$) (Table 3). Sites with deeper probing pocket depth and clinical attachment level were found to have relatively more soft tissue volumetric reduction ($p<0.001$). This finding suggests that PPD reduction can be expected at sites with deeper probing depths [29].

The main limitation of this study, except for the small sample size, is that we assumed that the reduction was solely attributed to the soft tissue component in the analysis of volumetric reduction. Nevertheless, it is possible to have both hard and soft tissue remodelling after non-surgical periodontal treatment [30]. In order to consider the degree of hard tissue remodelling, it may be possible to implement the use of CBCT in the analysis after NSPT. This could allow us to identify the changes in soft tissue components more accurately to analyse the correlation with the baseline and changes in periodontal clinical parameters. A recent study has combined intraoral scanning data with CBCT to identify the gingival dimension and compare it with clinical probing data [31].

Also, based on the fact that there was no tooth hypermobility greater than degree one detected at baseline examination, we have assumed that no apparent tooth movement would occur after non-surgical periodontal treatment. This assumption was based on some previous studies [32]. However, further consideration should be implemented to assess patients with increased periodontal disease severity.

Lastly, we have analysed the data at the tooth surface level in our study, which we would consider the buccal, palatal or lingual surface as a whole instead of analysing the six sites individually. This is due to the current limitation in dividing the sites accurately. Further investigations may consider the use of software which allows digital identification of the landmarks; a recent study has used the computer-aided method to identify and compare the changes in the gingival margin [15]. Suppose the intraoral scanning data can be divided into six sites per tooth, which resembles our clinical probing sites. In that case, this could directly compare the changes at that particular site. In addition, the effect of adjacent sites would be minimized, and possible correlations may be identified with higher accuracy.

In conclusion, we have identified some possible correlations between soft tissue volumetric reduction and baseline/changes in clinical periodontal parameters after NSPT. Based on this, the future direction could be the development of software focusing on analysing the respective correlation to aid in the periodontal diagnosis, assess treatment outcomes and assist in the periodontal risk assessment.

Author contribution statement

All authors gave their final approval and agreed to be accountable for all aspects of the work.

Credit author statement

Authors' contribution: MT and GP conceived the study. ET and MF contributed to the study design. ML and AK identified eligible subjects. ML and AK contributed to the study measurements and treatment provision. GP and MF analysed the study results. GP and MF prepared the manuscript draft. All authors contributed to the critical revision of the manuscript draft. All authors approved the final version.

Declaration of Competing Interest

No conflict of interest was reported. The authors do not have any financial interests, either directly or indirectly, in the products or information listed in the paper. The authors declare that there are no conflicts of interest in this study.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jdent.2023.104536.

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