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Digital and clinical approach to quantifying periodontal tissue changes after crown lengthening surgery: A case series pilot study

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Abstract

Crown lengthening surgery is a common periodontal procedure carried out to increase the amount of tooth exposure for aesthetic or restorative purposes. It is crucial for clinicians to understand the effect of crown lengthening surgery on the periodontal tissues to prevent relapse or over treatment. Even though various clinical parameters have been used by researchers in the past to quantify the amount of suprastructure exposed, the use of digital technology has not been widely adopted. The aim of this case series was to evaluate the changes in periodontal tissue after crown lengthening surgery with both clinical and digital approaches. This case series included five patients who underwent surgery at the Postgraduate Periodontics Clinic at the University of Otago over the period of six months. Clinical parameters such as probing depth, gingival recession, keratinised tissue height, plaque accumulation, gingival inflammation, crown height, gingival phenotype, and bone height were measured with a customised probing stent at baseline and 1-, 3-, and 6-month post-surgery. Digital impressions were also taken along with the clinical parameters to measure the volumetric changes. Most significant changes were observed in crown exposure, gingival recession and bone levels, followed by probing depth reduction for treated sites. Minimal changes were seen for the width of keratinised tissues, plaque levels and gingival scores. Volumetric changes were only significantly reduced after 6 months of healing. This case series found that crown lengthening resulted in an increase in tooth exposure and a reduction in tissue volume. Volumetric changes measured through sequential digital impressions were also comparable to clinical findings.

Keywords: *crown lengthening, periodontium, surgical flaps, volumetric analysis*

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Introduction

Surgical crown lengthening is a procedure designed to increase the amount of supragingival tooth structure for restorative and aesthetical indications (Gupta *et al.*, 2015). It can be carried out by clinicians to improve access and manage subgingival caries, tooth fractures, root resorptions or endodontic therapy perforations (Bennani *et al.*, 2017; Brägger *et al.*, 1992; Jepsen *et al.*, 2018). On the other hand, patients with excessive gingival display (delayed passive eruption) can benefit aesthetically by removing the excess periodontal tissue.

In order to have a predictable result after crown lengthening surgery, several factors need to be considered. The morphology and dimension of the dentogingival unit (DGU), which is the soft tissue compartment that is located at the cervical area of the tooth

coronal to the alveolar crest has to be evaluated carefully prior to crown lengthening surgery. It comprises of the junctional epithelium and the supracrestal connective tissue attachment of the gingivae. It has been reported that the average measurement for the supracrestal tissue attachment, also known as the "biological width", is on average 0.97 mm for the junctional epithelium and 1.07 mm for the supracrestal connective tissue attachment (Gargiulo *et al.*, 1961). Feasibility of performing this procedure is also highly influenced by the amount of keratinised tissue and supporting alveolar bone (Gupta *et al*., 2015; Nobre *et al.*, 2017).

An adequate periodontal-restorative interface determines tissue health. Accurate location of the prospective restoration margin prevents tissue inflammation associated with pathological probing depths and loss of periodontal supporting tissue. Likewise, it facilitates optimal access for oral home care procedures (Brägger *et al*., 1992; Carvalho *et al.*, 2020). Earlier studies measure periodontal tissue changes after crown lengthening surgery through various clinical parameters such as the distance between a custom stent fitted on the teeth to the free gingival margin and base of the probable pocket (Brägger *et al*., 1992). Even though this is a highly accurate method of tracking changes, other methods based on current technology are now emerging.

Intraoral scanners have increased in popularity in dentistry to create digital impressions instead of traditional impressions and stone casts (Richert *et al.*, 2017). In the last 5 years, multiple studies concluded that intraoral scanners are as accurate as physical stone casts (Mennito *et al*., 2019, Güth *et al*., 2016). However, only a few studies have used intraoral scanners to evaluate volumetric alterations. A study by Zhang and colleagues in 2021, concluded that intra-oral scanners can be recommended to evaluate morphological changes of the gingiva after initial periodontal therapy. Similar digital techniques have been successfully used to evaluate volumetric changes in periodontal plastic surgery to measure mucosal thickness a year after grafting with acellular dermal matrix (Papi *et al*., 2021). Furthermore, three-dimensional quantitative measurements have been carried out to assess buccal augmented tissue after modified coronally advanced tunnel technique combined with subepithelial connective tissue graft *(Fei et al*., 2021). The results of this study concluded that digital measurement by intraoral scanning is a non-invasive and reliable method to monitor volumetric changes after periodontal plastic surgery.

As of now, no guidelines nor recommendations exist for clinical studies regarding the use of a series of digital impressions to prospectively evaluate soft tissue volume changes after surgery (Tavelli *et al*., 2021). Currently, there is limited research evaluating volumetric periodontal tissue alterations after crown lengthening surgery (CLS).

Aim

The aim of this pilot study is to assess the volumetric and clinical changes in periodontal tissues after crown lengthening surgery at 1-, 3- and 6-month healing time.

Materials and Methods

Inclusion criteria

- Participants of ≥ 18 years of age who are being treated for crown lengthening surgery at the Postgraduate Periodontics Clinic at the Faculty of Dentistry, University of Otago
- Not undergoing active orthodontic therapy
- Absence of periodontitis
- Absence of pathologic tooth mobility or furcation involvement.

Exclusion Criteria

- Participants with systemic conditions contraindicated for periodontal surgery
- Pregnant and lactating females
- Smokers/vapers

Ethical approval was obtained from the University of Otago Human Ethics Committee (Health) (H21/167) and Research Consultation with Māori.

Parameters

As a part of the periodontal screening appointment, patients referred to the clinic for crown lengthening surgery over a recruitment period of six months underwent a standardised periodontal evaluation. Five patients, with one site requiring crown lengthening surgery each, met the criteria above and were included in this case series. Four of the sites were in the posterior sextant while one was in the anterior region Only one site was of a thin gingival phenotype. Intraoral scans were taken for both arches and bite registration to fabricate a customised probing stent as seen in Figure 1. Clinical photographs and radiographs were taken at different time points as shown in Figure 2a-2h.

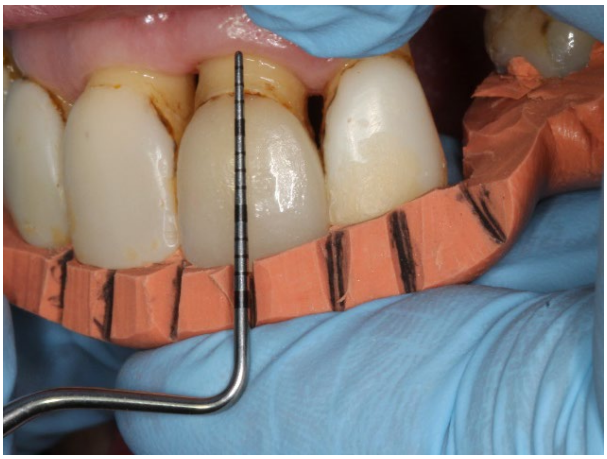
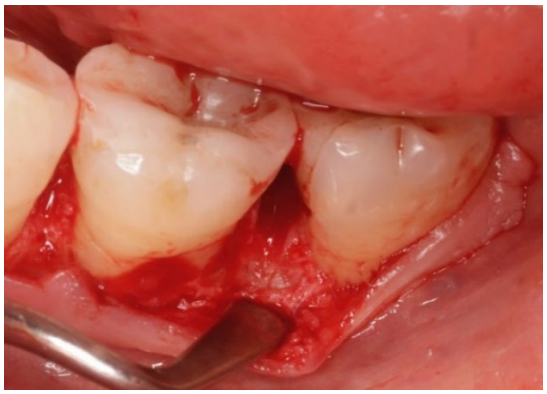


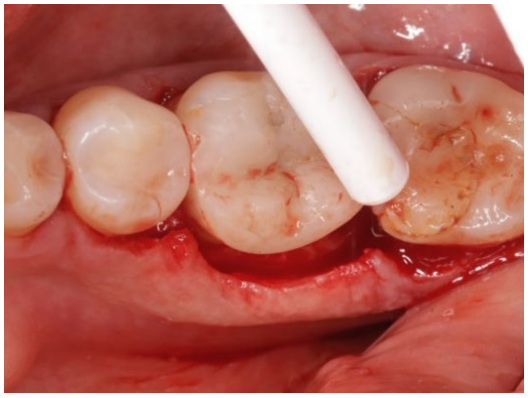
Figure 1. Buccal measurement with customised stent and UNC-15 probe.

(a) **(b)**

Figure 2. Clinical and radiographic images before and after crown lengthening surgery of 36. (a) Pre-operative buccal view, b) Pre-operative lingual view, c) Intra-operative buccal view, d) Intra-operative occlusal view, e) Pre-operative periapical radiograph, f) Post-operative periapical radiograph, g) Post-operative buccal view and h) Post-operative lingual view.



(c)



(d)

(e)

(f)

(g)

(h)

Figure 3. *(continued)*

The following periodontal clinical parameters of treated and adjacent teeth (adjacent tooth number 1 and number 2) were then recorded using a UNC - 15 University of North Carolina probe by an experienced and calibrated examiner (A.T.S). Periodontal probing depths, gingival recession, keratinised tissue height, plaque accumulation, gingival inflammation and crown height were measured at six sites per tooth: mesio-buccal (MB), mid-buccal (MidB), disto-buccal (DB), mesio-lingual(ML), mid-lingual (MidL) and disto-lingual (DL).

- Periodontal probing depth: measured in mm from the gingival margin to the bottom of the periodontal pocket.

- Gingival recession (GR): distance in mm from the cementoenamel junction (CEJ) or margin of the restoration to the gingival margin.

- Keratinised tissue height (KTH): distance in mm from the gingival margin to the mucogingival junction (buccal and lingual sites).

- Gingival phenotype (GP) was assessed at mid-buccal surfaces by inserting the periodontal probe within the gingival sulcus observing the periodontal probe shining through gingival tissue (Kan et al 2010):

    - Probe visible: thin (≤1 mm)
    - Probe not visible: thick (> 1 mm).

- Plaque accumulation: presence or absence after running periodontal probe (O'Leary et al., 1972).

- Gingival inflammation: presence or absence of bleeding after superficial gentle probing (Ainamo and Bay, 1975).

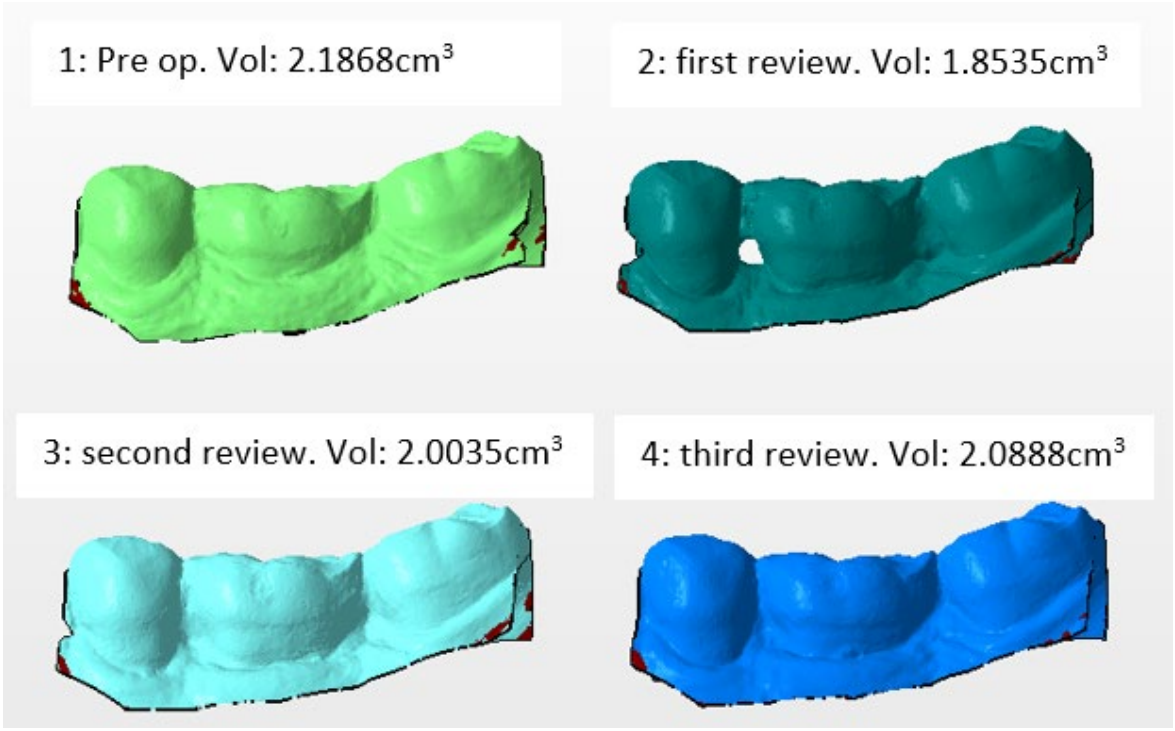
- Bone height: distance in mm from the CEJ to the most coronal aspect of the alveolar crest at mesial and distal sites of treated and adjacent sites were measured on periapical radiographs before and after crown lengthening.

- Crown exposure: distance in mm were measured for treated and adjacent sites in mm from the bottom edge of the customised stent to the gingival margin (GM).

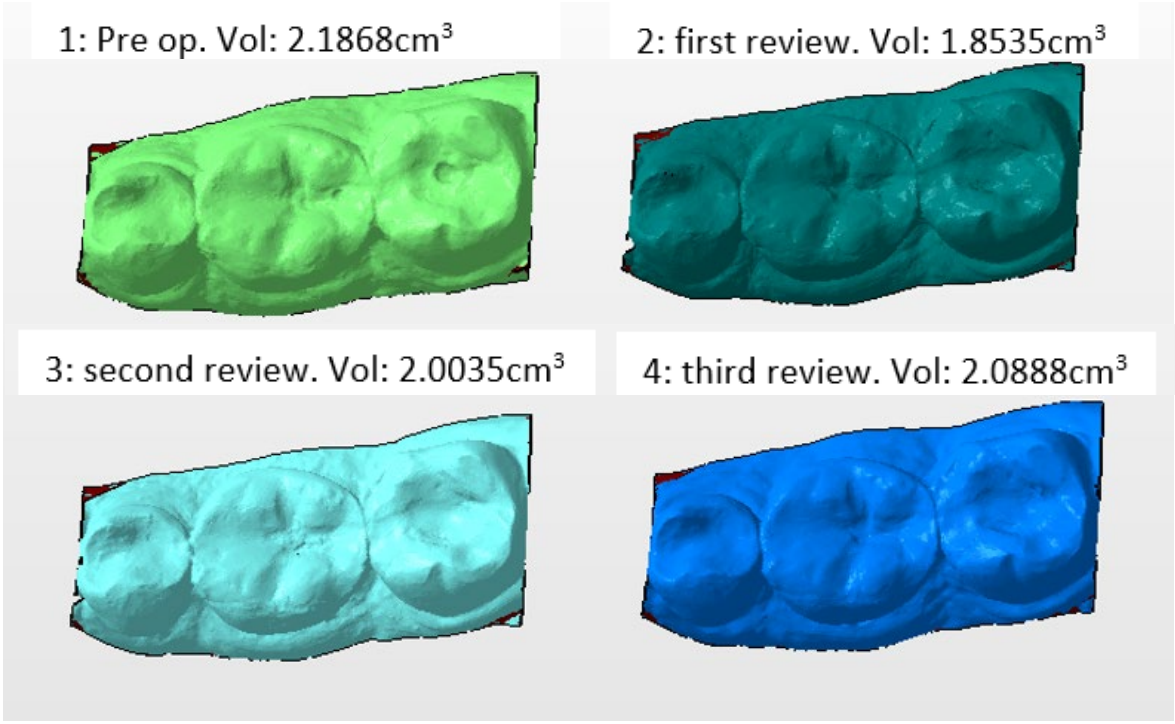
Three-dimensional volumetric evaluation: Digital intraoral impressions of participant's teeth and periodontium were obtained using a calibrated Trios 3 intraoral scanner (3Shape, Denmark), at baseline (before surgery), 1-, 3- and 6- months. The impressions were then exported and superimposed to measure the mean deviations (mm) and volumetric changes (mm^3) as seen in figure 3a – 3d (Autodesk Netfabb, United States).

Crown lengthening procedures were carried out by a DClinDent postgraduate student (R.G.) under the supervision of an experienced periodontist (A.T.S.). Four patients underwent surgery involving an apically repositioned flap and ostectomy while one patient had laser gingivectomy without osseous recontouring under local anaesthesia.

0.2% chlorhexidine mouthwash (Savacol, Colgate) was provided to the patients for two weeks following the procedure and the patients were advised not to use a toothbrush around the surgical area. Sutures were removed and the surgical area polished two weeks after the surgery and oral hygiene procedures reinstated.

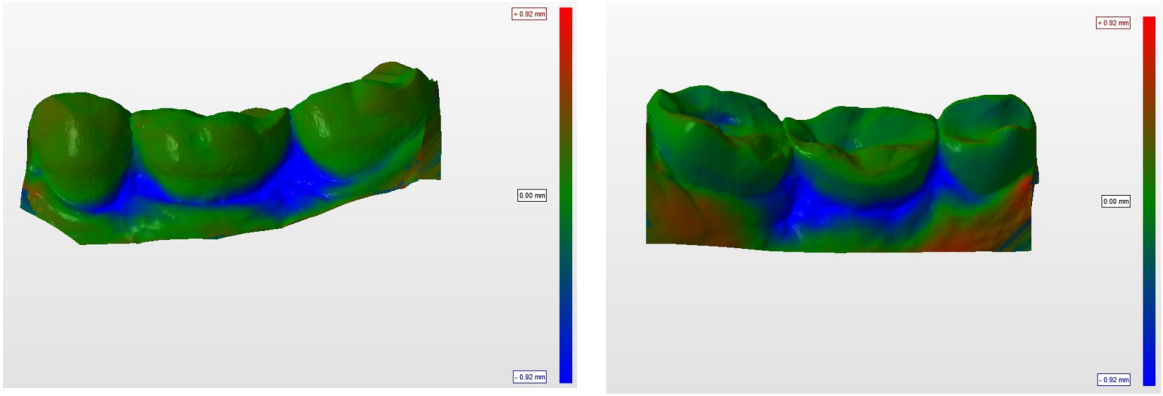


(a)



(b)

Figure 3. Comparison of digital volumetric changes between baseline and 1, 3, and 6-months (Colour images for different time points: Baseline: light green; 1-month: dark green; 3- month: light blue; 6-month: dark blue). a) Digital volumetric comparison (Buccal), b) Digital volumetric comparison (Occlusal), c) Digital volumetric comparison (Buccal), and d) Digital volumetric comparison (Lingual). Green areas in (c) and (d) indicate no difference in volume, blue areas indicate loss of tissue volume, while red areas indicate gain of tissue volume.



(c) **[d]**

Figure 4. *(continued)*

Statistical Analysis

The Shapiro test was used to analyse normality. In the case of normal distribution, the student t-test will be used to determine the statistical difference on the set parameters. In case of non-normality, the non-parametric method of Wilcoxon signed-rank test was used using a significance level (2-tail) of P-value < 0.05. A one-way ANOVA was used to analyse differences among baseline (initial evaluation) and healing time (1-, 3- and 6-month), using F-test, the outcome of a significant difference, as a result, will lead to a post hoc analysis of Tukey test to identify the time of significant difference. Means were calculated for all parameters. Pearson correlation was used to determine association across parameters. The Statistical analysis was performed using R software (The R Foundation for Statistical Computing, Vienna, Austria, www.R-project.org), and RStudio (Boston, USA).

Results

Gingival recession changes were statistically significant following crown lengthening surgery for all sites apart from adjacent tooth 2 at 6 months. An initial increase in recession between baseline and 3 months followed by a gradual decrease was seen in

all patients. The most significant changes occurred on the treated tooth between baseline and 1 and 3-month evaluation. The changes in probing depths were similar to recession. Adjacent tooth 1 and treated tooth had an initial decrease in probing depth, which continued to decrease over the observation period. Results for adjacent tooth 1 and treated tooth were all statistically significant when compared to baseline. The most significant changes occurred on the treated tooth (Table 1a, b).

The differences in crown exposure for adjacent tooth 1 and treated tooth were statistically significant throughout the study (table 2a). Overall, crown exposure increased at 1-month with minimal changes afterwards. The general trend of keratinised tissue levels, as shown by table 2b, showed a decrease from baseline to 1-month, followed by a slight increase at 3-months and then slightly more at 6-months. The only statistically significant results for keratinised tissue levels for all sites (adjacent tooth 1, treated tooth and adjacent tooth 2) were seen between baseline and 1-month.

Table 1. Changes in probing depths and gingival recession 1-, 3-, and 6-months compared to baseline following crown lengthening.

a. Probing depths (mm)					
		Mean ± (SD)	**Mean difference from baseline ± (SD)**	**95% CI**	**P-value**
Adjacent tooth 1	Baseline	2.77 ± (0.90)			
	1 month	2.20 ± (1.06)	0.57 (± 0.94)	0.22, 0.92	0.002
	3 months	2.37 ± (0.93)	0.40 ± (0.89)	0.07, 0.73	0.021
	6 months	2.50 ± (0.73)	0.27 ± (0.74)	-0.01, 0.54	0.058
Treated tooth	Baseline	2.83 ± (1.09)			
	1 month	2.10 ± (0.71)	0.73 ± (0.98)	0.37, 1,10	< 0.001
	3 months	2.20 ± (0.71)	0.63 ± (0.96)	0.27, 0.99	0.001
	6 months	2.37 ± (0.61)	0.47 ± (0.90)	0.13, 0.80	0.008
Adjacent tooth 2	Baseline	2.50 ± (0.94)			
	1 month	2.23 ± (0.77)	0.27 ± (0.69)	0.01, 0.52	0.043
	3 months	2.37 ± (0.67)	0.13 ± (0.73)	-0.14, 0.41	0.326
	6 months	2.27 ± (0.64)	0.23 ± (0.77)	-0.06, 0.52	0.109
b. Gingival recession (mm)					
		Mean ± (SD)	**Mean difference from baseline ± (SD)**	**95% CI**	**P-value**
Adjacent tooth 1	Baseline	1.03 ± (1.16)			
	1 month	1.80 ± (1.75)	-0.77 ± (1.45)	-1.31, -0.22	0.007
	3 months	1.67 ± (1.49)	-0.63 ± (1.30)	-1.12, -0.15	0.012
	6 months	1.43 ± (1.07)	-0.40 ± (0.86)	-0.72, -0.08	0.016
Treated tooth	Baseline	1.30 ± (2.02)			
	1 month	2.70 ± (1.66)	-1.40 ± (1.10)	-1.81, -0.99	< 0.001
	3 months	2.70 ± (1.64)	-1.40 ± (1.25)	-1.87, -0.93	< 0.001
	6 months	1.77 ± (1.50)	-0.47 ± (0.94)	-0.82, -0.12	0.011
Adjacent tooth 2	Baseline	0.57 ± (1.22)			
	1 month	0.90 ± (1.47)	-0.33 ± (0.76)	-0.62, -0.05	0.023
	3 months	0.83 ± (1.32)	-0.27 ± (0.52)	-0.46, -0.07	0.009
	6 months	0.70 ± (1.12)	-0.13 ± (0.57)	-0.35, 0.08	0.211
P-value compared to baseline, the unit of the analysis was the site not the patient					

Table 2. Changes in crown exposure and keratinised tissues (in mm) at 1-, 3- and 6-months compared to baseline following crown lengthening.

a. Crown exposure (mm)					
		Mean ± (SD)	**Mean difference from baseline ± (SD)**	**95% CI**	**P-value**
Adjacent tooth 1	Baseline	6.10 ± (2.59)			
	1 month	7.03 ± (2.57)	-0.93 ± (1.36)	-1.44, -0.42	< 0.001
	3 months	7.13 ± (2.92)	-1.03 ± (1.13)	-1.45, -0.61	< 0.001
	6 months	6.80 ± (2.72)	-0.70 ± (0.92)	-1.04, -0.36	< 0.001
Treated tooth	Baseline	6.13 ± (3.12)			
	1 month	7.50 ± (2.79)	-1.37 ± (1.33)	-1.86, -0.87	< 0.001
	3 months	7.47 ± (2.90)	-1.33 ± (1.27)	-1.81, -0.86	< 0.001
	6 months	6.93 ± (2.73)	-0.80 ± (1.06)	-1.20, -0.40	< 0.001
Adjacent tooth 2	Baseline	6.23 ± (2.78)			
	1 month	6.57 ± (2.50)	-0.33 ± (1.12)	-0.75, 0.09	0.115
	3 months	6.47 ± (2.73)	-0.23 ± (0.63)	-0.47, 0.00	0.050
	6 months	6.47 ± (2.87)	-0.23 ± (0.77)	-0.52, 0.06	0.109
b. Keratinised tissue (mm)					
		Mean ± (SD)	**Mean difference from baseline ± (SD)**	**95% CI**	**P-value**
Adjacent tooth 1	Baseline	4.77 ± (1.59)			
	1 month	4.50 ± (1.59)	0.27 ± (0.74)	-0.01, 0.54	0.058
	3 months	4.70 ± (1.70)	0.07 ± (0.64)	-0.17, 0.31	0.573
	6 months	4.77 ± (1.55)	0.00 ± (0.52)	-0.20, 0.20	1.000
Treated tooth	Baseline	5.23 ± (1.28)			
	1 month	4.93 ± (1.28)	0.30 ± (0.70)	0.04, 0.56	0.026
	3 months	5.03 ± (1.19)	0.20 ± (0.71)	-0.07, 0.47	0.136
	6 months	5.07 ± (1.08)	0.17 ± (0.53)	-0.03, 0.36	0.096
Adjacent tooth 2	Baseline	5.10 ± (1.12)			
	1 month	4.87 ± (0.86)	0.23 ± (0.50)	0.05, 0.42	0.017
	3 months	4.93 ± (0.94)	0.17 ± (0.53)	-0.03, 0.36	0.096
	6 months	5.10 ± (0.99)	0.00 ± (0.37)	-0.14, 0.14	1.000
P-value compared to baseline, the unit of the analysis was the site not the patient					

Throughout the observation period, both treated and adjacent sites maintained similar levels of plaque with low gingival inflammation levels. The results obtained for plaque and gingival indices showed no significant difference after crown lengthening surgery (Table 3).

The overall changes in the marginal bone levels associated with the surgical procedure were between 0.65 and 0.3 mm. The treated tooth had the highest bone level reduction when compared to the adjacent teeth. The treated site had significant bone level changes at 6 months (Table 4).

Table 3. Plaque and gingival indices recorded at adjacent and treated teeth.

	Adjacent tooth 1	Treated tooth	Adjacent tooth 2	*P*-value
Plaque index				
Baseline, n (%)				
Absent	15 (50.0)	13 (43.3)	15 (50.0)	0.837
Present	15 (50.0)	17 (56.7)	15 (50.0)	
One month, n (%)				
Absent	12 (40.0)	17 (56.7)	18 (60.0)	0.251
Present	18 (60.0)	13 (43.3)	12 (40.0)	
Three months, n (%)				
Absent	20 (66.7)	20 (66.7)	20 (66.7)	1.000
Present	10 (33.3)	10 (33.3)	10 (33.3)	
Six months, n (%)				
Absent	24 (80.0)	26 (86.7)	26 (86.7)	0.713
Present	6 (20.0)	4 (13.3)	4 (13.3)	
Gingival index				
Baseline, n (%)				
Absent	24 (80.0)	21 (70.0)	24 (80.0)	0.572
Present	6 (20.0)	9 (30.0)	6 (20.0)	
One month, n (%)				
Absent	21 (70.0)	24 (80.0)	24 (80.0)	0.572
Present	9 (30.0)	6 (20.0)	6 (20.0)	
Three months, n (%)				
Absent	25 (83.3)	25 (83.3)	26 (86.7)	0.919
Present	5 (16.7)	5 (16.7)	4 (13.3)	
Six months, n (%)				
Absent	27 (90.0)	27 (90.0)	29 (96.7)	0.538
Present	3 (10.0)	3 (10.0)	1 (3.3)	
Note: The unit of the analysis was the site and not the patient.				

Table 3. Bone level changes between baseline and 6-months following crown lengthening.

Bone level changes (mm)					
		Mean ± (SD)	**Mean Difference from baseline ± (SD)**	**95% CI**	**P-value**
Adjacent tooth 1	Baseline	3.12 ± (1.13)			
	6 months	3.64 ± (1.08)	-0.51 ± (0.79)	-1.08, 0.06	0.072
Treated tooth	Baseline	2.80 ± (2.02)			
	6 months	3.46 ± (1.96)	-0.65 ± (0.32)	-0.88, -0.43	< 0.001
Adjacent tooth 2	Baseline	2.50 ± (1.37)			
	6 months	2.87 ± (1.30)	-0.37 ± (0.51)	-0.73, 0.00	0.048
P-value compared to baseline; the unit of the analysis was the site not the patient					

Table 5 shows the volumetric changes at 1-, 3-, and 6- months compared to baseline. The results at 3 and 6 months were marginally statistically significant. A general trend was observed where volume tissue reduction was smaller at 1 month, and higher at 3 and

6 months. Although there was some tissue rebound at 1st month, volume changes were maintained after 3 months. Changes between 3 and 6 months were minimal, suggesting some degree of tissue stability. Superimposed digital impressions showed significant changes specially around the treated tooth and sites adjacent to the treated site. Greater changes are depicted with dark blue followed with sites with no change in green and rebound of tissue in red (Figure 3c and d).

Table 4. Volumetric changes at 1-, 3- and 6-months compared to baseline following crown lengthening.

Volumetric changes (cm^3)				
	Mean ± (SD)	**Mean difference from baseline ± (SD)**	**95% CI**	**P-value**
Baseline	2.184 ± (0.491)			
1 month	2.101 ± (0.540)	0.082 ± (0.149)	-0.103, 0.267	0.285
3 months	2.071 ± (0.445)	0.113 ± (0.092)	-0.002, 0.228	0.053
6 months	2.092 ± (0.458)	0.091 ± (0.072)	0.002, 0.181	0.047
Please note that due to the nature of the outcome, the unit of the analysis here is the patient.				

Discussion

Crown lengthening surgeries can affect the overall soft and hard tissue appearance. These volumetric changes may also extend to other sites. A systematic review published in 2017 reported that crown lengthening surgery can lead to clinical and aesthetic alterations on the adjacent/non-adjacent sites, which must be considered in the surgical planning phase (Nobre *et al.,* 2017).

Tissue stability changes after CLS has historically been evaluated using linear and radiographic measurements of treated and adjacent sites (Smith *et al.,* 2023). In line with the results of this study, other studies had also reported no statistically significant changes for plaque and gingival scores during the 6-month follow ups (Arora *et al.,* 2013; Brägger *et al.,* 1992). This is typically due to the strict inclusion criteria for these studies and for the surgery. In most cases, having stable periodontal health is required to undergo crown lengthening surgery as it provides the best surgical outcomes. As well as in this study, most other studies require plaque and gingival indices ≤1 (Arora *et al.*, 2013; Brägger *et al.,* 1992).

The initial increase in probing depth at treated and adjacent sites followed by a continual decrease over the observation period could be attributed to the healing and inflammation that took place within the first month. The result of this study is in line with other studies, which also showed decrease in periodontal probing between 3- and 6-months at both treated and adjacent sites (Arora *et al.,* 2013).

The results of the crown exposure from this study are also similar to other studies. The amount of crown exposure and tissue stability after CLS has been reported in various studies. Patient's age and sex, gingival phenotype, tooth type, location within the dental arch, postsurgical flap position, amount of bone reduction and surgical technique are factors that can influence tissue rebound (Arora *et al.,* 2013; Deas *et al.,* 2004; Lanning *et al.,* 2003). Most significant changes in tissue rebound are

seen at 3 months; however, additional changes have been reported at 12 months (Deas *et al.,* 2004; Lanning *et al.,* 2003). There were minimal differences in tissue rebound between anterior and posterior teeth after crown lengthening (Arora *et al.,* 2013).

Most healing and tissue rebound occurred within the first 3 months with very little tissue alterations occurring between 3 and 6 months (Arora *et al.,* 2013). Tissue rebound was found to be directly correlated with the periodontal phenotype. Thicker and flatter phenotypes showed greater tissue rebound (Arora *et al.,* 2013; Pontoriero & Carnevale, 2001). Other studies have also reported that thin periodontal phenotypes are less resistant to trauma or surgical insult, which increase its susceptible to gingival recession (Joshi *et al.,* 2016).

The bone level changes reported in this case series are consistent with the findings published by Brägger and colleagues in 1992. Due to the nature of the surgery and exposure of the alveolar bone, further minor decrease in bone level is expected due to surgical trauma. Osseous reduction typically ranges between 1 and 3 mm at treated sites, and ideally, a distance of 3 mm is recommended to secure adequate space to avoid invasion of the supracrestal tissue attachment (Brägger *et al.*, 1992; Gargiulo *et al.,* 1961). Bone reduction of < 1.50 mm results in an average crown lengthening of 1.53 mm whereas bone reduction of more than 1.50 mm achieves a mean gain in crown length of 1.95 mm after CLS (Arora *et al.,* 2013). Soft tissues changes are closely related with bone levels, insufficient ostectomy or no bone recontouring can lead to relapse due to soft tissue rebound (Deas *et al.,* 2004).

To the authors' knowledge, this is the first study that utilized 3-dimensional analysis to assess volumetric tissue changes following crown lengthening surgery. The volumetric findings of this study correlated to the clinical outcomes accurately. As a result of the resective nature of crown lengthening procedures, there was an overall decrease in tissue volume after surgery, which was marginally significant at 3 and 6 months, but not at 1 month. The lack of statistical significance at 1 month could be due to swelling related to the surgical trauma (Arora *et al.,* 2013). The use of sequential digital impressions to evaluate volume changes have been evaluated and validated in other periodontal surgeries such as periodontal plastic surgery and surgical therapy of peri-implantitis (Galarraga-Vinueza *et al.,* 2020; Marques *et al.,* 2021). These studies found volumetric analysis to be a straight-forward and non-invasive method to objectively quantify periodontal outcomes. As digital technology continues to evolve in dentistry, volumetric results obtained from digital impressions will be even more precise.

Conclusion

In summary, the results obtained from this pilot study are comparable to other published studies. Most significant changes were observed in crown exposure, gingival recession, and bone levels, followed by probing depth reduction for treated sites. Volumetric changes were only significantly reduced after 6 months of healing while the width of keratinised tissues, plaque levels and gingival scores had minimal changes throughout the observation period. Volumetric changes measured through a series of digital impressions in this pilot study reflected on the clinical findings accurately. Future research with larger sample sizes and longer follow-up periods should be considered to further our understanding of the changes in the periodontium following crown lengthening surgery.

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References

Ainamo J. & Bay I. (1975). Problems and proposals for recording gingivitis and plaque. International Dental Journal, 25(4):229-35. PMID: 1058834.

Arora, R., Narula, S. C., Sharma, R. K., & Tewari, S. (2013). Evaluation of supracrestal gingival tissue after surgical crown lengthening: A 6-month clinical study. *Journal of Periodontology*, 84(7), 934-940. https://doi.org/10.1902/jop.2012.120162

Bennani, V., Ibrahim, H., Al-Harthi, L., & Lyons, K. M. (2017). The periodontal restorative interface: Esthetic considerations. *Periodontology 2000*, 74(1),74-101. https://doi.org/10.1111/prd.12191

Brägger, U., Lauchenauer, D., & Lang, N. (1992). Surgical lengthening of the clinical crown. *Journal of Clinical Periodontology,* 19(1), 58-63.

Carvalho, B. A. S., Duarte, C. A. B., Silva, J. F., Batista, W. W. d. S., Douglas-de-Oliveira, D. W., de Oliveira, E. S., *et al.* (2020). Clinical and radiographic evaluation of the Periodontium with biologic width invasion. *BMC Oral Health*, 20(1), 1-6.

Deas, D. E., Moritz, A. J., McDonnell, H. T., Powell, C. A., & Mealey, B. L. (2004). Osseous surgery for crown lengthening: A 6-month clinical study. *Journal of Periodontology*, 75(9), 1288-1294. https://doi.org/10.1902/jop.2004.75.9.1288

Fei, X., Rui, Z., Yu, C., Yong, Z., Ni, K., & Qingxian, L. (2021). *BMC Oral Health*. https://doi.org/10.21203/rs.3.rs-136367/v1

Galarraga-Vinueza, M. E., Obreja, K., Magini, R., Sculean, A., Sader, R., & Schwarz, F. (2020). Volumetric assessment of tissue changes following combined surgical therapy of peri-implantitis: A pilot study. *Journal of Clinical Periodontology,* 47(9), 1159-1168. https://doi.org/10.1111/jcpe.13335

Gargiulo, A. W., Wentz, F. M., & Orban, B. (1961). Dimensions and relations of the dentogingival junction in humans. *Journal of Periodontology*, 32(3), 261-267. https://doi.org/https://doi.org/10.1902/jop.1961.32.3.261

Gupta, G., Gupta, R., Gupta, N., & Gupta, U. (2015). Crown lengthening procedures-A review article. *IOSR Journal of Dental and Medical Sciences*, 14(4), 27-37.

Jepsen, S., Caton, J. G., Albandar, J. M., Bissada, N. F., Bouchard, P., Cortellini, P., *et al.* (2018). Periodontal manifestations of systemic diseases and developmental and acquired conditions: Consensus report of workgroup 3 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *Journal of Periodontology*, 89(S1), S237-S248. https://doi.org/https://doi.org/10.1002/JPER.17-0733

Lanning, S. K., Waldrop, T. C., Gunsolley, J. C., & Maynard, J. G. (2003). Surgical crown lengthening: evaluation of the biological width. *Journal of Periodontology*, 74(4), 468-474. https://doi.org/10.1902/jop.2003.74.4.468

Marques, T., Santos, N. M., Fialho, J., Montero, J., & Correia, A. (2021). A new digital evaluation protocol applied in a retrospective analysis of periodontal plastic surgery of gingival recessions. *Scientific Reports*, 11(1), 20399. https://doi.org/10.1038/s41598-021-99573-6

Nobre, C. M. G., de Barros Pascoal, A. L., Albuquerque Souza, E., Machion Shaddox, L., dos Santos Calderon, P., de Aquino Martins, A. R. L., *et al.* (2017). A systematic review and meta-analysis on the effects of crown lengthening on adjacent and non-adjacent sites. *Clinical Oral Investigations*, 21(1), 7-16.

O'Leary, T. J., Drake, R. B., Naylor, J. E. (1972). The plaque control record. *Journal of Periodontology*, 43(1),38. https://doi.org/10.1902/jop.1972.43.1.38

Papi, P., Penna, D., Di Murro, B., & Pompa, G. (2021). Clinical and volumetric analysis of peri-implant soft tissue augmentation using an acellular dermal matrix: A prospective cohort study. *Journal of Periodontology*, 92(6), 803-813. https://doi.org/10.1002/JPER.20-0219

Pontoriero, R., & Carnevale, G. (2001). Surgical Crown Lengthening: A 12-Month Clinical Wound Healing Study. *Journal of Periodontology*, 72(7), 841-848. https://doi.org/10.1902/jop.2001.72.7.841

Smith, S.C., Goh, R., Ma, S., Nogueira, G.R., Atieh, M., Tawse-Smith, A. (2023), Periodontal tissue changes after crown lengthening surgery: A systematic review and meta-analysis, *The Saudi Dental Journal,* 35(4), 294-304,, https://doi.org/10.1016/j.sdentj.2023.03.004

Tavelli, L., Barootchi, S., Majzoub, J., Siqueira, R., Mendonça, G., & Wang, H.-L. (2021). Volumetric changes at implant sites: A systematic appraisal of traditional methods and optical scanning-based digital technologies. *Journal of Clinical Periodontology*, 48(2), 315-334. https://doi.org/https://doi.org/10.1111/jcpe.13401