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Treatment of teeth with insufficient clinical crown. Long-term clinical outcomes of a minimally invasive crown lengthening approach: a retrospective analysis.

Running Title: Long term outcomes of minimally invasive crown lengthening

Pierpaolo Cortellini, MD DDS*#§, Simone Cortellini DDS MSc*§, Daniele Bonaccini DDS*, Gabrielle Stalpers DDS*, Aniello Mollo DDS*, Jacopo Buti**

*Private Practice, Florence, Italy

#Accademia Toscana di Ricerca Odontostomatologica (ATRO) Florence, Italy

§Section of Periodontology, Department of Oral Health Sciences, KU Leuven & Dentistry, University Hospitals, KU Leuven, Leuven, Belgium

** Unit of Periodontology, UCL Eastman Dental Institute, London, UK

Correspondence to: Dr Pierpaolo Cortellini, Via Carlo Botta 16, 50136 Firenze, Italy. Email: sandro@cortellini.org

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Abstract

Aims: Aim of this retrospective study was to evaluate the incidence of complications and to determine the long-term survival rate of teeth with severely compromised clinical crowns treated with minimally invasive crown lengthening (MICL) and restorative treatment.

Methods: A sample of 112 teeth in 86 patients was treated with MICL and restorative dentistry. Endodontic and orthodontic therapy was applied when needed. Clinical outcomes were assessed at baseline, 1 year and long-term.

Results: The application of MICL resulted in very limited radiographic bone resection (RBR, 1 ± 0.1 mm on average). Limited local inflammation and shallow probing depth were detected at 1 year (2.6 ± 0.5 mm) and long-term (2.9 ± 1.0 mm). Most of the teeth (76.8%) maintained dental and periodontal health over time. The negative events observed in 26 teeth were caries

(8.9%), fractures (7.1%), endodontic problems (1.8%), periodontal problems (4.5%) and restoration problems / complications (0.9%). The survival rate was 90.2%.

Conclusions: the outcomes of this long-term retrospective analysis (8.9 ± 0.9 years, range 8 to 10) show high tooth survival rates and low incidence of complications of teeth treated with MICL and restoration of the clinical crown. *Int J Periodontics Restorative Dent 2023. doi: 10.11607/prd.6992*

Key words: Crown lengthening, clinical trial, biologic width, microsurgery, reconstructive dentistry, long-term

Introduction

Teeth structurally compromised by advanced conditions such as deep caries, fractures, iatrogenic lesions or existing restorations often require a multidisciplinary intervention including endodontics, orthodontics and reconstructive dentistry; not unfrequently, a surgical crown lengthening procedure is needed in order to provide adequate access and isolation of the cervical margin of the lesion, ensure adequate crown length and avoid an infringement of the supracrestal connective tissues. Historically, an elongation of the clinical crown ranging from 3 to 5 mm has been suggested by several authors drawing upon the considerable variability of the so called "biologic width" [1-10]. The term "biologic width" has been renamed "supracrestal tissue attachment width" as per the 2017 consensus of the American Academy of Periodontology and the European Federation of Periodontology[11]. Recently, a minimally invasive crown lengthening (MICL) approach has been proposed to reduce the amount of flap reflection and bone resection[12]. This approach has demonstrated favourable 1-year clinical and patient outcomes [12,13].

The treatment of severely compromised teeth requires multidisciplinary intervention and the prognosis is influenced by multiple risk factors[13]. Recently, a flow-chart that incorporates a composite risk-evaluation model has been proposed to guide this challenging decisional process [14]. Although several studies have provided evidence to support comparable survival rates of dental implants and compromised but successfully treated natural teeth [15-18], to date, limited evidence is available regarding the long-term outcomes of teeth with severely compromised clinical crown treated with surgical crown lengthening and reconstruction [19-21].

The aim of this retrospective study was to evaluate the incidence of complications and the long-term survival rate in teeth with severely compromised clinical crowns treated with multidisciplinary intervention, including MICL and restorations.

Materials and Methods

Study population and experimental design

This is a retrospective analysis from a periodontal case registry cohort established at the practice of the authors in Florence, Italy, in accordance with the Helsinki Declaration on experimentation involving human subjects, as revised in 2013. The present retrospective analysis was approved by the local ethical committee for clinical research of the Health Service of Tuscany (University Hospital of Firenze protocol ATRO2019, registration n° 15106_oss). All subjects gave informed written consent.

Study population is represented by a sample of 86 consecutive patients participating in our supportive periodontal care (SPC) that received the last clinical examination between January 2020 and December 2021. They reported to our clinic in a period spanning January 2010 – December 2013 for the reconstruction of 112 teeth presenting with caries, fractures, restorations or crowns to be replaced. After removal of caries / fractured fragments / pre-existing reconstructions, the intrasulcular cervical margin was located at a distance ≤1mm from the bottom of the sulcus. This condition was considered a violation of the supracrestal tissue attachment and treated with MICL

Patients received endo treatment and orthodontic extrusion, when necessary, provisional reconstruction, MICL, and definitive reconstruction. Patients participated into a supportive periodontal care (SPC) program.

Baseline clinical records

Before surgery (baseline) an independent calibrated clinician (DB) recorded: 1. full mouth plaque scores (FMPS, as percentage of total surfaces which revealed the presence of plaque); 2. full mouth bleeding scores (FMBS, as the percentage of total surfaces bleeding on probing); 3. pocket depth (PD) and bleeding on probing (BOP, assessed dichotomously) at the site associated with the most apical position of the cervical lesion with a periodontal probe (PCP UNC 15, Hu-Friedy). 4. the DMFT (Decayed / Missing / Filled Teeth) index. Patients were classified as healthy or presenting either with gingivitis or periodontitis. The cause of the clinical crown destruction was registered, along with the sequence of interventions necessary for the resolution of the clinical problem.

1-year and long-term clinical records

At follow-up visits, the same calibrated clinician (DB) recorded: 1. FMPS and FMBS; 2. complications or recurrences of the treated teeth that occurred after the definitive restauration; 3. PD and BOP at the treated teeth.

Measurements on radiographs

Periapical radiographs were taken before crown lengthening (baseline), after the reconstruction and at the long-term follow-up visits. The following parameters were measured by an independent calibrated clinician (SC): 1. Distance from the cervical margin of the restauration and the alveolar bone (CM-BC); 2. Distance from CM and the apex of the tooth (CM-A). The radiographs were measured with an electronic ruler at a 10x magnification (Sorriso, Ver. 13, Dental Trey, Italy) on a high-definition monitor at a resolution of 1600 X 1200 pixels. The ratio between the linear measurements of pre- and post-treatment root length were calculated for the individual pair of radiographs ((RL0/RL1 and RL1/RL2) and used to correct the distortion of post-treatment and follow-up linear measurements.

Clinical approach

A step by step treatment approach was adopted as reported in previous papers [12-14]. In brief, the clinical crown was cleared to expose healthy dentin, and endodontic treatment or re-treatment applied, when needed, by an expert operator (AM). Insufficient clinical crown was defined as a condition in which endodontic treatment and / or reconstructive therapy would have been not applicable for the very deep position of the cervical margin or applicable but detrimental for the supracrestal tissue attachment. The type of reconstruction was chosen, either a direct or an indirect reconstruction or a full crown. A careful evaluation of the position of the cervical margin with respect to the supracrestal tissue attachment was done. When the cervical margin was located very deep, orthodontic extrusion was planned before surgery. Main reasons for orthodontic extrusion were: 1. aesthetics, when the apical positioning of the flap would cause a misalignment of the gingival margin; 2. The need for large removal of supporting bone at the neighbouring teeth; 3. The risk of invasion of furcations at the neighbouring teeth. Then MICL was performed. The restorations were performed by two expert operators (GS, AM) after surgery with the following timing: 1. Early reconstruction (3 weeks after surgery) when direct or indirect reconstructions were chosen 2. Late reconstruction (> 3 weeks after surgery) in cases restored with full crowns.

Surgical approach

Surgery consisted of apically positioned flaps with or without bone surgery. Full thickness envelope-like flaps were elevated. A periosteal fenestration was made apical to the mucogingival junction (MGJ) when necessary to apically position the buccal flap. The cervical margin (CM) of the reconstruction was detected as the most apical portion of healthy dentin when a direct or an indirect restoration were chosen. When a full crown was planned, an extra space of at least 2 mm was added to ensure the ferrule effect. The distance between the CM and the alveolar bone was measured with a periodontal probe. When this distance was 2.0 mm or greater, ostectomy was not performed, while when the distance was <2 mm ostectomy was performed to reach 2.0 mm distance between the CM and the bone. The root surface was planed with a curette for an extension of 2.0 mm apical to the CM removing all the supracrestal fibres. Osteoplasty was performed when necessary to improve bone anatomy and favour flap adaptation. Ostectomy and osteoplasty were extended to the neighbouring teeth to create a flat to positive bone / gingival anatomy.. The flap margin was sutured at the level of the crestal bone and sutured with external mattress sutures. Patients received one tablet of iboprufen

600mg at the end of surgery and a second compulsory dose after 6 hours. A protocol for the control of bacterial contamination consisting of 0.12% chlorhexidine mouth rinsing three times per day was prescribed. Patients were requested to avoid hard brushing, flossing and chewing in the treated area for a period of 3 weeks. From week 1 to week 3, patients were instructed to apply a postsurgical toothbrush (Vitis Surgical, Barcelona, Spain) and requested to apply light interdental brushing / flossing. Then they resumed full oral hygiene. Patients were recalled at week 1, when sutures were removed, and 3. At each visit, local gentle debridement of the treated area and full mouth prophylaxis were performed. At the end of the reconstructive phase, patients were enrolled in a 3 to 6-months supportive care program, according to individual needs.

All the surgical procedures were performed by an experienced clinician (PC) with the aid of an operating microscope (Global Protege, St Louis, Mo). A stringent post-surgical protocol was enforced [12]. Representative cases are reported in Figures 1-3.

Data analysis

Data were expressed as means ± standard deviation for continuous variables and frequency and percentage for dichotomous ones. To account for the cluster nature of the data (multiple treated teeth within the same patient), mixed effect models were implemented with the patient as the random effect. To estimate changes within different time points for continuous outcomes (PD, Rec, CM-BC, FMPS and FMBS) data were organised in a long format and post-hoc Bonferroni corrections were applied. Between-group differences for periodontitis *vs.* healthy/gingivitis patients at different time points were also estimated using a wide data format. A survival analysis at tooth level was conducted to create Kaplan-Meier curves for the negative events grouped by caries, need for tooth extraction, need for non-surgical and surgical periodontal re-intervention based on the number of years from the surgical crown lengthening procedure. Data were censored at long-term follow-up re-assessment. In case of more than one negative event for the same tooth (i.e., caries and tooth extraction), the year of the event resulting in the tooth failing (i.e., tooth extraction) was considered. Competing cause analysis for negative events observed between the time of the surgical crown lengthening procedures and the long-term follow-up re-assessment was conducted and survival plots were generated. All statistical comparisons were conducted at the 0.05 level of significance. JMP Pro version 16.2.0 and Jamovi version 2.3.21.0 statistical software packages were used.

Results

Baseline patient and teeth characteristics

Treatment was performed on 112 teeth (86 patients, 52 women), mean age 45.0 ± 12.1 years (range: 20 to 76 years), 9 smokers (13.3 ± 5.9 cigarettes/day; range: 3 to 20) and 2 former smokers for > 10 years. Eight patients were diagnosed as healthy, 52 with gingivitis, and 26 with periodontitis. Mean baseline FMPS and FMBS were 39.7% ± 23.0% and 20.4% ± 18.1%, respectively. The treated teeth were: 1 incisor (maxilla), 30 premolars (20 maxillary), and 81 molars (34 maxillary). Reasons for intervention were caries (82 teeth), fracture (6 teeth), and need to replace a pre-existing crown (24 teeth). The baseline reconstructive and endodontic conditions are reported in Table 1.

Outcomes of surgical and reconstructive phase

After cause-related therapy, average FMPS was 12.0% ± 3.8% (range: 3% to 21%) and average FMBS was 8.0% ± 2.6% (range: 1% to 15%). Differences with baseline were clinically and statistically significant (P < 0.001). Average PD (Table 2) was 3.2 ± 0.6 mm (range: 2 to 5 mm). PD was deeper in the periodontitis patients (3.4 ± 0.8 mm) than in the healthy/gingivitis patients (3.1 ± 0.5 mm); the difference was not statistically significant (P = 0.060). BOP was detected in 39 sites (34.8%), of which 25 (33.3%) in periodontitis patients. The average presurgical radiographic CM–BC (Table 2) was 1.6 ± 0.8 mm (range: –1.2 to 4.6 mm), which was greater in periodontitis patients (1.8 ± 0.9 mm) than in healthy/gingivitis patients (1.5 ± 0.7 mm); the difference was statistically significant (P = 0.031). The type of definitive tooth restoration is reported in Table 1. Four teeth were treated with orthodontic extrusion before surgery, 42 teeth received endodontic treatment, and 41 teeth received endodontic re-treatment (Table 1). Crown lengthening was performed before endodontic treatment in 29 sites to allow for proper field isolation. The postsurgical radiographic measurements report an average CM–BC of 2.6 ± 0.7 mm (range: 1.3 to 4.8 mm). The difference between preoperative and postoperative measurements (radiographic bone resection [RBR]) averaged 1 ± 0.1 mm, and was statistically significant (P < 0.001). An RBR < 2 mm was seen in most cases (93.8%). When splitting the population into subgroups by presurgical CM–BC measurements (< 2 mm and ≥ 2 mm), the RBR was significantly greater for CM–BC < 2 mm (1.1 ± 0.7 mm vs 0.7 ± 0.6 mm; P = 0.002). No difference (P = 0.381) was detected in the amount of RBR between periodontitis patients (0.9 ± 0.6 mm) and healthy/gingivitis patients (1.0 ± 0.7 mm). Statistically significant greater average RBR was measured in teeth restored with a full crown *vs.* direct restorations (P = 0.021) and indirect restorations *vs.* direct restorations (P = 0.015), while no differences were observed between full crown and indirect restorations (P = 1.000) (Table 3).

1-year clinical outcomes

At 1 year (Table 2), average FMPS was 13.1% ± 2.7% (range: 7% to 19%) and average FMBS was 7.8% ± 3.0% (range: 1% to 15%). Differences compared to presurgical re-evaluation were statistically significant for FMPS (P = 0.013) but not for FMBS (P = 0.540). The average PD was 2.6 ± 0.5 mm, with a PD reduction of 0.6 ± 0.1 mm (P < 0.001). PD averaged 2.6 ± 0.6 mm in the periodontitis patients and 2.5 ± 0.5 mm in the healthy/gingivitis patients (P = 0.508). BOP was detected in 11 sites (9.8%), of which 3 in periodontitis patients, with a significant reduction compared to baseline. On 8 teeth (7.1%) the cervical margin of the restoration was located supra-gingivally, while on the other 104 (92.9%) it was either at or within the gingival sulcus.

Long-term clinical outcomes

The 112 teeth were re-evaluated after an average follow-up period of 8.9 ± 0.9 years (range: 8 to 10). The mean recalls frequency per year was 1.9 ± 0.6 (range: 0.8 to 3.1). Average FMPS was 14.0% ± 3.9% (range: 4% to 25%) and average FMBS was 10.7% ± 3.4% (range: 2% to 21%) (Table 2). For FMPS, differences were statistically significant compared to presurgical re-evaluation (P = < 0.001) but not to the 1-year follow-up measurements (0.112). For FMBS, the differences were significant for both time points comparisons (P < 0.001). The average PD was 2.9 ± 1.0 mm, with a PD reduction of 0.3 ± 0.1 mm (P = 0.001) compared to 1-year follow-up. PD averaged 3.1 ± 1.1 mm in the periodontitis patients and 2.8 ± 1.0 mm in the healthy/gingivitis patients (P = 0.216). BOP was detected in 34 sites (32.4%), 10 sites in periodontitis patients, with a statistically significant reduction compared to baseline (P < 0.001). On 13 teeth (12.4%) the cervical margin of the restoration was located supra-gingivally, while on the other 92 (87.6%) it was either at or within the gingival sulcus.

The long-term radiographic measurements report an average CM–BC of 2.6 ± 0.7 mm (range: 1.4 to 5.3 mm). The difference between preoperative and long-term was statistically significant (average 1.0 ± 0.1 mm, P < 0.001), while no significant changes were detected between postoperative and long-term (average 0.1 ± 0.1 mm, P = 1.000). No difference (P = 0.605) was detected in the CM-BC distance between periodontitis (2.8 ± 0.7 mm) and healthy/gingivitis patients (2.6 ± 0.7 mm).

A total of 26 teeth (23.2%) in 26 patients had at least one complication which required intervention. Ten teeth (8.9%) in 10 patients developed carious lesions, 8 (7.1%) in 6 patients fractured, 2 (1.8%) in 2 patients required endodontic re-treatment, 1 (0.9%) a new restoration. The DMFT score was not significantly associated with the incidence of carious lesions (P = 0.112). Periodontal re-intervention was required on 5 teeth (4.5%) in 5 patients, non-surgical subgingival instrumentation in 3 teeth (2.7%) and a surgical procedure in 2 teeth (1.8%).
Eleven teeth (9.8%) in 11 patients were extracted during the follow-up period due to fracture (8), caries (1), and endodontic (2) reasons. Most of the teeth that experienced fracture had or received complex and multiple dental interventions during the “active phase of treatment”: 10 were endodontically treated, 9 were reconstructed with a crown, 9 had at least one interproximal contact with an adjacent tooth, 2 were bridge abutments and 6 had an endodontic post (Table 5).

A survival analysis was conducted to estimate the time-to-event probability where the negative event was classified as the need for: i) periodontal intervention; ii) caries management; or III) tooth extraction, observed between the time of the surgical crown lengthening procedures and the long-term follow-up re-assessment. Competitive cause analysis was conducted and reported in Table 4. Survival Plot is reported in Figure 4.

Discussion

The long-lasting debate on either saving or replacing severely compromised teeth remains a significant clinical challenge. Overall, patients prefer saving teeth [22-23].

In the present study, 86 out of 112 teeth (76.8%) presenting with severely compromised clinical crown and treated with multidisciplinary interventions maintained dental and periodontal health over a period of 8 to 10 years. Complications and/or need for re-intervention were observed in 26 teeth (23.2%); in particular, 10 (8.9%) developed caries, 8 (7.1%) fractured, 2 (1.8%) required endodontic re-treatment, 5 (4.5%) presented with a periodontal problem and 1 (0.9%) required a new restoration. These data are in line with the outcomes of previous studies [19,21]. The hypothesis that high caries risk patients may face a greater risk of recurrences [21,24] is not supported by our data, since no correlation was found between the baseline DMFT and the recurrences of caries.

The overall survival rate was 90.2% at 8.9 ± 0.9 years (range: 8 to 10) that positively compares with the 88.3% survival rate at 5 years, 78.4% at 10 years and 68.1% at 15 years reported by Ashnagar et al (2019)[21]. The superior outcomes observed in our study might be attributed, at least in part, to the distinct clinical settings in which the treatment was performed, a well-coordinated team of experienced clinicians versus graduate residents and predoctoral students. Retrospective studies from Patil et al (2016)[20] on 25 teeth with an average follow-up of 4.2 years and Dibart et al (2003)[26] on 26 teeth with a 5-year follow-up, reported a 100% survival rate for the treated teeth. Observation from the present study indicated that the negative events leading to eventual tooth extraction occurred progressively over time (Tables 4 & 5 and Fig 4). It is thereby reasonable to expect high survival rates during the initial 5-year period with a subsequent rise in the incidence of negative events in the following years. Most of the extracted teeth were already heavily restored at baseline or received complex and multiple dental interventions during the “active phase of treatment” (Table 5). It is, thereby, reasonable to hypothesize that survival of teeth depends, at least in part, by the baseline clinical presentation, with a higher likelihood of complications associated with more complex initial conditions. In order to increase the clinical success and survival rate it is thereby important to perform a thorough pre-operative assessment [14].

A critical aspect to take into account when assessing the outcomes of this study is the consistent implementation of a minimally invasive approach. From a restorative perspective, efforts were always made to avoid unnecessary removal of residual tooth structure. From a periodontal perspective, a minimally invasive crown lengthening approach was applied [12,13].

The underlying principle of MICL was to reach a “minimal supracrestal tissue attachment width” of 2.5 mm, including supracrestal connective tissue, junctional epithelium and a free space between the cervical margin of the restoration and the bottom of the sulcus [10-12]. Flaps were sutured at the level of the bone crest. High-quality reconstructions were applied early in the postoperative period with full visibility and accessibility of the cervical margin before the anticipated coronal migration of the gingival tissues [5,7,27].

The minimal apical displacement of the periodontal tissues achieved through the application of MICL, along with the early initiation of restorative procedures and subsequent postsurgical soft tissue rebound, led to the marginal or intrasulcular positioning of the majority of cervical margins of the restorations at the one-year follow-up. Despite this, data from the present study show 1-year healthy periodontal conditions and a remarkable long-term stability of the tissues, with shallow PD, a limited number of BOP-positive sites, and stability of the radiographic bone levels (Table 2). These observations support the hypothesis that optimal restoration margins allocated within the gingival sulcus, without encroaching upon the supracrestal attachment apparatus do not induce gingival inflammation, given that patients adhere to self-performed plaque control and participate in SPC programs [11,28].

It should be underlined that the reported outcomes have been obtained mainly on teeth allocated on posterior sextants. In addition, since this procedure requires a multidisciplinary approach, the external validity of the obtained data needs to be further verified.

Within the limits of a retrospective analysis, the outcomes observed in this study show high tooth survival rates and low incidence of complications and support the hypothesis that it is possible to preserve periodontal health in sites treated with MICL and the intrasulcular allocation of high-quality cervical margins not infringing the supracrestal attachment apparatus, provided that patients are motivated and actively participate in a supportive periodontal/dental care program.

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Authors contribution: Dr. P Cortellini contributed to the design of the study and wrote the manuscript with input from all the other authors. Dr P Cortellini, Dr A Mollo and Dr G Stalpers treated the patients. Dr. D Bonaccini made the clinical measurements. Dr S Cortellini made the radiographic measurements. Prof J Buti contributed to data interpretation and made the statistical analysis. All Authors helped in interpreting the results and revised the manuscript. All Authors reviewed and approved the submitted manuscript.

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Tables

Table 1 Teeth Treated with Minimally Invasive Crown Lengthening (MICL) and Crown Restoration.

		Endodontic condition, n		
Type of clinical crown restoration	Total, n	No Endo Tx	Endo Tx	Endo Re-Tx
Baseline				-
Restoration	69	50	19	-
Full Crown	34	5	29	-
No Restoration	9	9	0	-
Total	112	64	48	-
After MICL				
Direct restoration	15	13	2	0
Indirect restoration	13	6	6	1
Full Crown	84	10	34	40
Total	112	29	42	41

Restoration = direct or indirect restoration; No restoration = teeth without any restorative reconstruction; No Endo Tx = teeth without any endodontic treatment, either vital or nonvital; Endo Tx = teeth with endodontic treatment; Endo Re-Tx = endodontic re-treatment.

Table 2 Presurgical, 1-Year and long-term clinical parameters of the crown-Lengthening group.

	Presurgical	**1 year**	**Pre-surgical-1y difference**	**P-value**	**Long-term**	**Presurgical - long-term difference**	**P-value**	**1y - long-term difference**	**P-value**
	Mean (SD)	Mean (SD)	Mean (SE)		Mean (SD)	Mean (SE)		Mean (SE)	
FMPS, %	12.0 ± 3.8	13.1 ± 2.7	1.0 ± 0.4	0.013*	14.0 ± 3.9	1.9 ± 0.4	<0.001*	0.9 ± 0.4	0.112
FMBS, %	8.0 ± 2.6	7.8 ± 3.0	-0.2 ± 0.4	0.540	10.7 ± 3.4	2.7 ± 0.4	<0.001*	2.9 ± 0.4	<0.001*
PD, mm	3.2 ± 0.6	2.6 ± 0.5	-0.6 ± 0.1	<0.001*	2.9 ± 1.0	0.3 ± 0.1	0.002*	-0.3 ± 0.1	0.001*
CM–BC, mm	1.6 ± 0.8	2.5 ± 0.6§	1.0 ± 0.1	<0.001*	2.6 ± 0.7	1.0 ± 0.1	<0.001*	0.1 ± 0.1	1.000

FMPS = full-mouth plaque score; FMBS = full-mouth bleeding score; PD = pocket depth; REC = distance between the apical margin of the restoration and the gingival margin; CM–BC = radiographic distance between the cervical margin of the restoration and the crestal bone. All p-values estimated by mixed effect models using the patient as random effect and time as a factor. *Statistically significant differences. § Measured after surgical crown lengthening.

Table 3 Ostectomy Measured on Radiographs in Teeth Restored with Full-Crown or Conservative (Direct/Indirect) Restorations.

RBR	Direct Restorations (n)	Indirect Restorations (n)	Full Crowns (n)	Total (n)
< 1 mm	12	5	42	59
≥ 1, < 2 mm	3	7	36	46
> 2 mm	0	1	6	7
Total	15	13	84	112

RBR = Radiographic Bone Resection

Table 4. Survival and competing cause analysis for negative events observed between the time of the surgical crown lengthening procedures and the long-term follow-up re-assessment.

Summary				
	Negative Events	**Number Censored**	**Mean**	**SE**
Total	24	89	9.88	0.24
Competing Causes				
			α*	**β***
Extraction	11	101	20.53	2.59
Caries Management	8	105	44.46	1.68
Periodontal Therapy	4	109	82.97	1.46

SE = Standard Error. *Weibull Parameter Estimates

Table 5 Status and characteristic of extracted teeth.

Tooth	Reason for Extraction	Year of Extraction	Years from MICL	Endodontically Treated	Crown	Interproximal Contact	Bridge Abutment	Enodontic Post
1	Fracture	2012	2	Yes	Yes	Yes	No	No
2	Fracture	2012	4	Yes	Yes	Yes	Yes	Yes
3	Endo Reason	2015	5	Yes	Yes	Yes	No	No
4	Endo Reason	2016	6	Yes	Yes	Yes	No	Yes
5	Fracture	2016	6	No	No	Yes	No	No
6	Fracture	2016	6	Yes	No	Yes	No	No
7	Fracture	2017	7	Yes	Yes	Yes	No	Yes
8	Fracture	2017	9	Yes	Yes	No	No	No
9	Fracture	2018	10	Yes	Yes	Yes	No	Yes
10	Caries	2018	10	Yes	Yes	No	Yes	Yes
11	Fracture	2018	10	Yes	Yes	Yes	No	Yes

Figures Legends

Fig 1a-j. Lower left first and second molar presenting with overhanging and infiltrated restorations and periapical lesions (a,b). The restorations have been removed and endodontic re-treatment performed (c). The clinical crowns have been elongated with MICL (d). Note the minimally invasive teeth preparation for the indirect teeth restorations (e,f). 1-year clinical and radiographic images (g,h). 10- year clinical and radiographic images showing the healthy conditions of the gingival and bone tissues (i,j).

Fig 2a-j. Upper left first premolar presenting with a deep caries (a). After removal of the decayed dentin and root canal treatment, the planned cervical margin resulted allocated at bone level and the tooth was planned for orthodontic extrusion (b) . Radiographic (c) and clinical (d) images at the end of orthodontic extrusion: note the misalignment of the gingival margin. After flap elevation an insufficient distance of 1.5mm between cervical margin of the restoration and bone is evident (e). The distance has been increased to 2mm with bone resective surgery and the root surface carefully planed to bone level (f). This distance was deemed sufficient to allow for the allocation of an indirect reconstruction without need for a ferrule effect. One-year clinical (g) and radiographic (h) images of the overlay applied on the premolar. Clinical (i) and radiographic (J) images at 10-year follow-up.

Fig 3a-i. First upper left molar presenting with a deep mesial caries; the tooth was vital (a). Endodontic treatment was deemed necessary (b) and was followed by orthodontic extrusion (c,d). After ostectomy and root planing the flap was apically positioned (e). One year clinical and radiographic images of the tooth restored with a crown (f,g). Ten-year clinical (h) and radiographic (i) images.

Fig 4. Survival Plot for negative events observed between the time of the surgical crown lengthening procedures and the long-term follow-up re-assessment.
Dotted line shows survival probability after omitted cause analysis for ‘Caries Management’ and ‘Periodontal Therapy’.

Figures


Fig 1a


Fig 1b


Fig 1c


Fig 1d

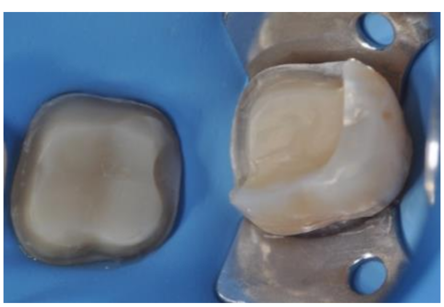


Fig 1e


Fig 1f


Fig 1g


Fig 1h


Fig 1i

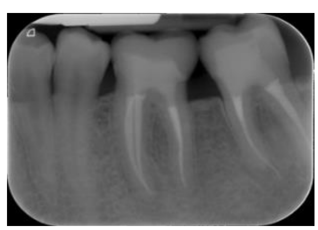


Fig 1j

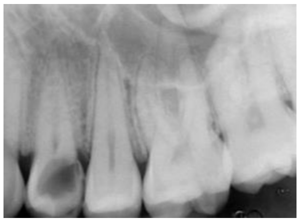
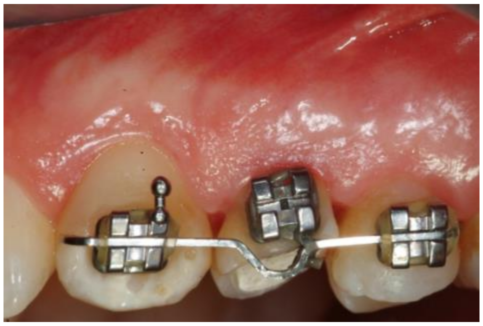


Fig 2a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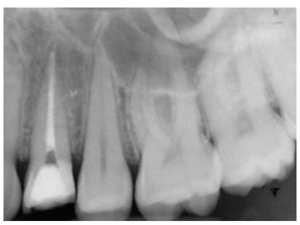
Fig 2c


Fig 2d


Fig 2e


Fig 2f


Fig 2g

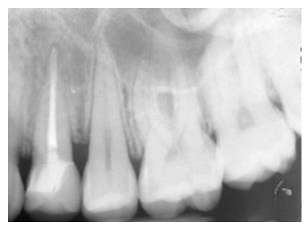
Fig 2h


Fig 2i

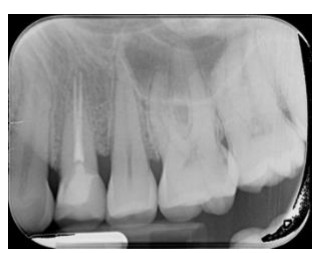
Fig 2j


Fig 3a


Fig 3b


Fig 3c


Fig 3d

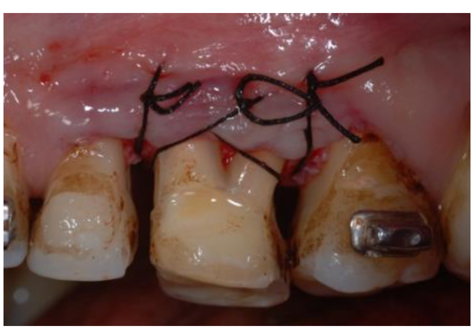
Fig 3e


Fig 3f


Fig 3g


Fig 3h


Fig 3i

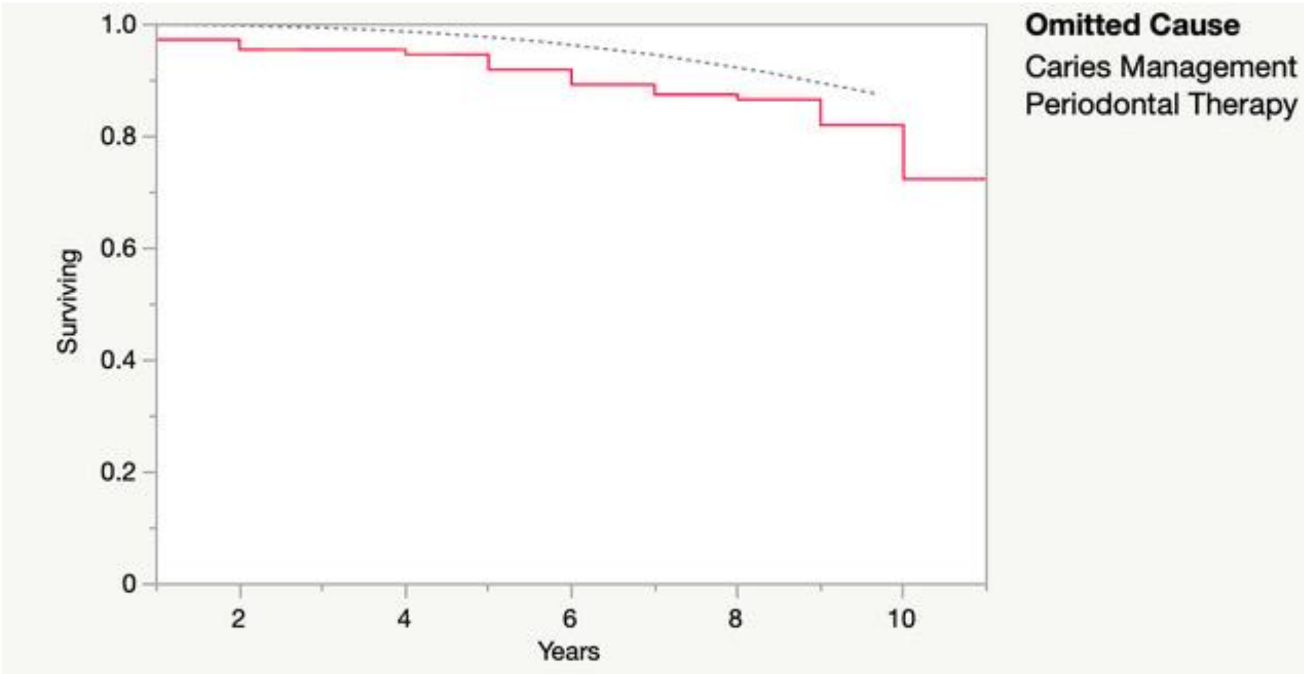
Omitted Cause
Caries Management
Periodontal Therapy
Surviving
1.0
0.8
0.6
0.4
0.2
0
2
4
6
8
10
Years

Fig 4