Crown Lengthening in Mandibular Molars: A 5-Year Retrospective Radiographic Analysis

Serge Dibart,* Diego Capri,* Ibrahim Kachouh,† Thomas Van Dyke,* and Martha E. Nunn*

Background: Crown lengthening procedures are a significant part of the periodontist's armamentarium. In order to recreate the clinical space lost to caries or trauma necessary for prosthetic restoration, osseous surgery is often required. If the procedure is not carefully planned, it may result in furcation involvement of multirooted teeth.

Methods: Twenty-six subjects with 26 mandibular molar teeth requiring crown lengthening procedures prior to prosthetic crown placement were evaluated. Nineteen subjects with 24 prosthetic crowns on lower molars which had not undergone crown lengthening were included as control teeth. Bite-wing radiographs prior to surgery (for the test group) or placement of the crown (control group) and 5 years after completion of the prosthesis were compared and analyzed.

Results: Of the 26 test teeth, 10 teeth (38.5%) were found to have radiographic evidence of furcation involvement, whereas none of the control teeth developed furcation invasions.

Conclusion: A critical distance from the furcation (CDF) of 4 mm was established as a landmark under which, if surgery was performed on mandibular molars, chances of furcation involvement in the future were very high. *J Periodontol 2003;74: 815-821.*

KEY WORDS

Furcation/etiology; furcation/prevention and control; molar; tooth crown.

* Department of Periodontology and Oral Biology, Boston University School of Dental Medicine, Boston, MA.
† Information Technology Department., Boston University School of Dental Medicine.

Extensive caries, short clinical crown, traumatic injury, or severe parafunctional habits may limit the amount of tooth structure available to properly restore an affected tooth. In situations in which a tooth has a clinical crown deemed inadequate for the retention of a required cast restoration, it is necessary to increase the size of the clinical crown by crown lengthening. This procedure enables the dentist performing the prosthetic restoration to develop an adequate zone for crown retention without extending the crown margins deep into periodontal tissues. When the margins of the restorations are placed deep subgingivally to overcome the affected area and/or to increase the retention of the crown, this may violate the entity known as "biological width." This term was defined as the sum of the junctional epithelium and supracrestal connective tissue attachment.[1]

Gargiulo et al. measured the dentogingival junction in humans and found that the average space occupied by the sum of the junctional epithelium and the supracrestal connective tissue fibers was 2.04 mm.[2] Violation of that space by restorations impinging on the biological width has been associated with gingival inflammation, discomfort, gingival recession, alveolar bone loss, pocket formation, etc., as shown in humans[3] and dogs.[4,5] In order to have a harmonious and successful long-term restoration, Ingber et al. advocated a 3 mm distance of sound supracrestal tooth structure between bone and prosthetic margins.[6] Some authors[7-9] favor an amount >3 mm to allow for adequate space during restorative maneuvers above the gingival tissues. Other authors[10] consider the entire gingival complex (gingival margin to the alveolar crest) to be a more accurate measurement to work with than individual dentogingival compartments. Smukler and Chaibi described how a predetermined entity called supracrestal gingival tissue (SGT), which differs from site to site, will re-form after surgical excision and how this "regrowth" will be dictated by the underlying anatomy of the dental and osseous units.[11] These findings have been confirmed by a recent 12-month clinical wound healing study in humans.[12]

The restoration of an adequate biological width and the creation of an adequate space for the proper placement of prosthetic margins on a compromised tooth can be achieved surgically[13,14] (crown lengthening procedure) or orthodontically (forced eruption), or by a combination of both.[15,16] When a surgical crown lengthening procedure (CLP) is planned, the anatomy of the involved tooth must be carefully evaluated, especially when the tooth structure lost or damaged approximates the furcation area of a molar. A careful evaluation of the position of the furcation entrance, in relation to the length of the root trunk, should precede the surgery. In general, the evaluation of the position of the furcation opening in mandibular molars is done through radiographic imaging of the area. Bite-wing radiographs are extremely helpful in the preoperative analysis. The superiority of bite-wings over periapical radiographs in representing anatomical spaces has been reported.[17,18]

The purpose of the present investigation was to retrospectively evaluate the outcome of crown lengthening surgery prior to final crown placement on mandibular molars. This study was done in an effort to determine a value below which a crown lengthening procedure can be detrimental to the periodontium. We called this value "critical distance from the furcation" (CDF), and it is calculated as the distance in millimeters from the furcation entrance to the margin of the temporary crown or excavated caries line.

MATERIALS AND METHODS

A total of 45 patients (18 males and 27 females; age 47.82 ± 14.46 years) were selected from the patient pool at the Boston University School of Dental Medicine based on the following criteria: they had to be free from periodontal disease and had to have their first or second mandibular molar crowned. They were divided into 2 groups. The study group included 26 patients who had received a prosthetic crown after a crown lengthening procedure. The control group included 19 patients who had received a prosthetic crown without undergoing crown lengthening. The selection of patients for both the study group and the control group consisted of all patients within a 1-year period who met the criteria for inclusion and had complete clinical and radiographic records from the initial crown placement to a follow-up period of 5 years. The total number of teeth studied was 50 (study group: 26; control group: 24). The study group patients had been referred initially to the periodontology clinic for crown lengthening prior to restorative work. All surgical procedures were carried out by periodontal residents. The main surgical objective was to create adequate space in order to allow for the placement of a restoration that would be respectful of the gingival and periodontal tissues. A dimension of 3 mm coronal to the alveolar crest was deemed necessary to permit healing, restoration of the biological width, and proper restoration of the tooth.[6] All restorative work was completed by dental school students within a year from the initial consultation. The treated patients (study and control groups) were then retrospectively evaluated 5 years after crown cementation, by comparing pre- and post-treatment bite-wing radiographs. Furcation involvement was determined by the presence of a radiolucent area showing bone loss in the furcation. The CDF was calculated by measuring the radiographic distance, in millimeters, from the tip of the furcation to the most apical point of the excavated caries or provisional restoration margin line (initial CDF) and to the margins of the final prosthetic crown (final CDF). The use of bite-wing radiographs in a dental school setting allowed for standardization of the radiographic equipment, film, and protocol, allowing for minimal distortion and accurate measurement.

RESULTS

There were 26 subjects with 26 crowns on lower molars (19 first molars, 7 second molars) in whom crown lengthening procedures were performed. Furcation involvement was determined by radiograph examination. None of the 24 control teeth (17 first molars, 7 second molars) had radiographic evidence of furcation involvement. Of the 26 test teeth, 10 teeth (38.5%) were found to have radiographic evidence of furcation involvement. Eight of these (80%) were mandibular first molars. Frequency distribution of control subjects and test subjects by gender, smoking status, and furcation involvement is given in Table 1. Fisher's exact test revealed no statistically significant differences in gender, smoking status, or molar type distributions between test and control subjects. However, Fisher's exact test indicated that there was a significant difference in the proportion of lower molars with furcation involvement between test subjects (subjects treated with crown lengthening) and control subjects (subjects not treated with crown lengthening) ($P = 0.002$). Specifically, lower molars receiving full crowns treated with crown lengthening were significantly more likely to exhibit radiographic signs of furcation involvement

Table 1.

Frequency Distribution

Parameter	No Crown Lengthening (Control)	Crown Lengthening (Test)	P*
Gender			
Male	42.1% (8/19)	38.5% (10/26)	
Female	57.9% (11/19)	61.5% (16/26)	1.000
Smoking status			
Non-smoker	84.2% (16/19)	88.5% (23/26)	
Smoker	15.8% (3/19)	11.5% (3/26)	0.686
Furcation			
No involvement	100% (19/19)	61.5% (16/26)	
Involvement	0% (0/19)	38.5% (10/26)	0.002
Molar type			
1st molar	70.8% (17/24)	73.1% (19/26)	
2nd molar	29.2% (7/24)	26.9% (7/26)	1.000

* *P* values based on 2-tailed Fisher's exact test.

Table 2.

Summary Statistics by Group

Parameter	N	Mean	SD	Median	Range	P*
Age (years)						
Control	19	51.8	12.4	50.0	32 to 71	
Test	26	47.6	11.1	45.5	31 to 70	0.231
Initial CDF (mm)						
Control	19	4.50	1.17	4.0	2 to 7	
Test	26	4.21	1.40	4.5	3 to 7	0.469
Final CDF (mm)						
Control	19	3.16	0.88	3.0	2 to 5	
Test	26	2.38	1.40	2.5	0 to 7	0.029

* *P* values based on 2-tailed independent sample *t* tests.

compared to lower molars receiving full crowns not treated with crown lengthening. Fisher's exact test was also used to determine whether there was a significant difference in the distribution of furcation involvement between first and second molars in both the complete data set as well as data that included only lower molars treated with crown lengthening. No significant difference in the occurrence of furcation involvement between first and second molars in either case was detected.

Summary statistics for age, initial CDF value, and final CDF value by treatment group are given in Table 2, based on the subject as the unit of observation. Multiple observations within subjects in the control group were averaged for each subject, and these subject means were used in the calculation of the summary statistics. Independent sample *t* tests were conducted to test for differences in age, initial CDF value, and final CDF value between test subjects and control subjects.

The only statistically significant difference detected was for final CDF values, with control teeth having significantly greater critical distance at follow-up after placement of a full crown compared to the CDF value of test teeth at follow-up after placement of a full crown ($P = 0.029$).

Summary statistics were computed for age, initial CDF value, and final CDF value by furcation involvement for test teeth only (lower molars treated with crown lengthening) (Table 3). Mann-Whitney U test was performed to compare age, initial CDF level, and final CDF level between test teeth that developed furcation involvement and test teeth that did not develop furcation involvement. There was no significant difference in age between test teeth developing furcation involvement and test teeth not developing furcation involvement. However, there were significant differences in initial CDF levels and final CDF levels between test teeth that developed furcation involvement and test teeth that did not develop furcation involvement. Specifically, test teeth that developed furcation involvement had significantly smaller initial CDF levels ($P < 0.001$) as well as significantly smaller final CDF levels ($P < 0.001$) compared to test teeth that did not develop furcation involvement. In addition, mandibular first molars appeared to be more at risk for developing furcation involvement after crown lengthening procedures (Tables 4 and 5).

DISCUSSION

The results of this study indicate that crown lengthening is related to the development of furcation involvement

Table 3.

Summary Statistics by Furcation Involvement Among Lower Molars Treated with Crown Lengthening Procedure

Parameter	N	Mean	SD	Median	Range	P*
Age (years)						
No furcation involvement	16	49.1	11.2	47.5	33 to 70	
Furcation involvement	10	45.2	10.9	45.2	31 to 70	0.356
Initial CDF (mm)						
No furcation involvement	16	5.13	0.81	5.0	4 to 7	
Furcation involvement	10	2.75	0.72	3.0	2 to 4	<0.001
Final CDF (mm)						
No furcation involvement	16	3.28	0.84	3.0	2 to 5	
Furcation involvement	10	0.95	0.76	1.0	0 to 2	<0.001

* *P* values based on Mann-Whitney U test.

Table 4.

Frequency Distribution of Furcation Involvement by Molar Type

Parameter	1st Molar	2nd Molar	Total	*P**
No furcation involvement	77.8% (28/36)	85.7% (12/14)	80.0% (40/50)	
Furcation involvement	22.2% (8/36)	14.3% (2/14)	20.0% (10/50)	0.704

* *P* values based on Fisher's exact test.

Table 5.

Frequency Distribution of Furcation Involvement by Molar Type Among Lower Molars Treated with Crown Lengthening Procedure

Parameter	1st Molar	2nd Molar	Total	*P**
No furcation involvement	57.9% (11/19)	71.4% (5/7)	61.5% (16/26)	
Furcation involvement	42.1% (8/19)	28.6% (2/7)	38.5% (10/26)	0.668

* *P* values based on Fisher's exact test.

following the placement of a full crown when the CDF is < 4 mm. All test teeth in this study with an initial CDF level < 4 mm eventually developed a furcation involvement (Figs. 1 and 2), while none of the test teeth with an initial CDF level > 4 mm developed a furcation involvement (Figs. 3 and 4). Of the 4 test teeth with an initial CDF level of 4 mm, only one (25%) eventually resulted in furcation involvement. Having noticed that more teeth in the test group than in the control group presented with endodontic treatment, an association between endodontic therapy and furcation involvement was analyzed using a chi-square test and was found not to be significant.

The dimension of the dentogingival junction, named biological width by Cohen,[1] as measured by Gargiulo et al.,[2] is equal to 2.04 mm. Others later revisited the concept in an attempt to identify a reliable value to be used whenever the biological width needed to be restored, to ensure healthy tissues surrounding the prosthetic restoration. The measurements reported by Gargiulo et al. were challenged by Vacek et al. in 1994, who studied human autopsy specimens and obtained a slightly reduced average value for the biological width.[19] They reported 1.14 mm as an average number for the junctional

Figure 1.
Bite-wing radiograph showing tooth #31 before crown lengthening procedure.

Figure 2.
Bite-wing radiograph showing tooth #31 five years after final crown cementation. Notice the furcation involvement.

Figure 3.
Bite-wing radiograph showing tooth #30 before crown lengthening procedure.

Figure 4.
Bite-wing radiograph of tooth #30 after crown lengthening, and final crown 5 years later. There is no furcation involvement.

epithelium (versus 0.97 mm reported by Gargiulo et al.[2]) and 0.77 mm as an average for the connective tissue fibers (versus 1.07 mm reported by Gargiulo et al.[2]). They agreed on the superior variability of the epithelium compared to the connective tissue part of the biological width. When Vacek et al.[19] grouped the average biological width according to the position of the teeth in the arch, they found values that were in line with Gargiulo et al.[2] (2.08 mm as the average biological width in molars compared to 2.04 mm as described earlier[2]). This is in agreement with what was originally reported by Waerhaug in 1953.[20] In that report, margins were kept 0.4 mm from the bottom of the sulcus and did not impinge on the connective tissue fibers. As a result, they were surrounded by tissues free from inflammatory cells.

The amount necessary to restore the biological width is still a subject of controversy. As we searched the literature, it became apparent that universal agreement on the biological width's value has not yet been reached. In 1977, Ingber et al.[6] advocated 3 mm as the minimum dimension of tooth structure that should be present coronal to the bone crest to allow proper prosthetic restoration and long-term periodontal health. Rosenberg et al.[7] and more recently Becker et al.[9] advocated a minimum of 4 mm above the bone crest to achieve periodontal and prosthetic success. In 1989, Wagenberg et al.[8] increased the value to 5 to 5.25 mm of sound tooth structure above the osseous crest in order to obtain similar results. In light of these controversial opinions, the papers published by Kois[10] and Smukler and Chaibi[11] seem to confirm the importance of a careful case-by-case analysis of the local anatomy and the distance from the gingival margin to the crest of bone (or SGT).

The anatomy of mandibular molars has been described extensively by several authors.[21-23] Wheeler described how the location of the buccal furcation entrance is usually 3 mm apical to the cemento-enamel junction (CEJ), while on the lingual, the same average distance increases to 4 mm.[21] Gher and Vernino[22] reported the same values in 1980, and they observed that second molar roots were usually more closely approximated than those of first molars, with a significantly higher incidence of partial or complete root fusion. In the same study, they showed how the root trunk of second mandibular molars is generally longer than that in first molars. This feature may have a protective role and explain the lower incidence of furcation invasion in the second mandibular molars when compared to first molars. Dunlop and Gher[23] measured anatomical parameters related to first mandibular molars and found that root separation usually occurred 4 mm apical to the CEJ and, in no case, did the tooth present with a root trunk longer than 6 mm.

The use of bite-wing radiographs to assess pre- and postoperative conditions was dictated by the accuracy factor. The most accurate reproduction of an object is achieved when the x-ray beam is perpendicular to the object. In routinely executed bite-wings of posterior sextants, the x-ray beam angle to the teeth ranges between 80 and 90 degrees, versus values between 70 and 90 degrees for periapical radiographs.[18] The use of a long cone parallel technique with Rinn's film holders while taking bite-wing radiographs is intended to achieve utmost accuracy and minimal distortion. Reed and Polson[17] showed significant differences in measurements taken from the CEJ to the bone crest on periapical radiographs versus bite-wings. This was true in 50% of the tooth surfaces studied, and 94% of the measurements were greater when made on bite-wings. The discrepancies found in measuring on different types of radiographs are the result of diverse x-ray beam angulations; measuring on normal periapical radiographs may often result in underestimation of the distances studied.

For the clinician, it is always a challenge to determine the long-term prognosis of a posterior tooth whose cusp has been severely fractured or that has extensive carious lesions or tooth wear. The same clinical condition judged amenable to treatment by one clinician may be deemed hopeless by another. This study tried to develop a new criterion that will help the clinician determine the best course of action in the treatment of damaged mandibular molars. From our statistical results, it appears that 40% of the test teeth developed a furcation lesion radiographically visible 5 years after crown cementation. All the test teeth with an initial CDF < 4 mm developed the lesion, while none of the test teeth with a CDF > 4 mm showed signs of periodontal furcation involvement. A CDF of 4 mm seems to be an important threshold in predicting long-term periodontal health. The CDF value is tightly related to the anatomy of the involved tooth and particularly to the length of the root trunk. On average, the root trunk of a mandibular molar is 4 mm;[23] therefore, it would appear that whenever the destruction of tooth structure invades the space below the CEJ, we may be dealing with an unfavorable CDF value. This, in turn, may be conducive to future periodontal breakdown if a crown needs to be placed after crown lengthening. It is worth noticing that out of the 4 teeth with a CDF value of exactly 4 mm, one tooth (25%) developed radiographic furcation involvement at the 5-year landmark.

Reasons for such a phenomenon to occur could include surgical exposure of the furcation itself, violation of the biological width, surgical trauma accompanying the exposure of the furcal bone, or a combination. Violation of a biological width of slightly more than 2 mm by prosthetic margins may cause bone loss in the furcation.[3-5] As for bone loss associated with the surgery, Wilderman et al.[24] and Wood et al.[25] studied the long-term healing following osseous surgery. The histological repair after surgery showed osteoblasts at work 1 year after the procedure. According to their data, on average after surgical exposure, an initial crestal bone loss of 1.2 mm was followed by new bone apposition, with a final loss of 0.8 mm of crestal bone height. The measured range varied between 0.11 mm to 3.1 mm, and the local anatomy of the bone seemed to be determinant to the amount of bone loss.[24]

It is reasonable then to think that the more bone we remove in the furcation area during crown lengthening, the more likely we are to have postoperative bone resorption that will encroach on the furcation opening, especially if the initial CDF is < 4 mm. Some authors have suggested that in order to minimize the postoperative bone resorption, one has to avoid damaging the supracrestal connective tissue fibers.[26]

In the present study, we attempted to retrospectively analyze bite-wings of lower molars to see whether a minimal distance existed from the margin of the temporary crown to the furcation entrance (CDF value) below which following crown lengthening surgery, periodontal health could not be maintained 5 years after crown cementation.

Based on the results of our study, there is evidence that crown lengthening procedures contribute to the development of furcation involvement among lower molars and that initial CDF values can be used to predict which lower molars will eventually develop furcation involvement if they are treated with crown lengthening. Larger studies should be conducted to confirm the results obtained in this study and to determine whether there is a potential solution to this problem among teeth with limited CDF that require treatment with crown lengthening in order to prepare the tooth for a full crown. One of the shortcomings of this study is the crude method of measuring the distances on the radiographs: we used a plastic grid with 1 mm intervals. This is a preliminary study. Hopefully, larger studies in the future and better measuring technology will give us more definite answers.

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Correspondence: Dr. Serge Dibart, Department of Periodontology and Oral Biology, Boston University School of Dental Medicine, 100 East Newton Street, Room G-217, Boston, MA 02118.

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