Original Article

Mechanical or cold lateral compaction: The incidence of dentinal defects

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ABSTRACT

Background: The incidence of dentinal defects may influence the outcome of root canal treatment. The aims of this study were to evaluate and compare the incidence of dentinal defects following root canal obturation with two different techniques.
Materials and Methods: A total of 110 mesial roots of human mandibular first molars were selected. Twenty-seven roots were left unprepared as negative controls (NCs). The mesiobuccal canals of 83 roots were prepared using rotary instruments. Twenty-seven roots were left unobturated as positive controls (PCs). Twenty-eight roots were obturated with cold lateral compaction (CLC) technique and the others were obturated with mechanical lateral compaction (MLC) technique. In the CLC and MLC groups, spreader penetration depth was measured by an electromechanical testing machine in canals containing master Gutta-percha cones. After root canal obturation, all the roots were sectioned horizontally at four levels from the apex and evaluated under a stereomicroscope at a magnification of ×40. The presence of dentinal defects was noted. Data were analyzed using the Chi-square and t-tests.
Results: The number of defects was not significantly different between the CLC, MLC, and PC groups. The CLC, MLC, and PC groups had significantly more defects compared to the NC group.
Conclusion: According to the results of this study, the MLC and CLC techniques were the same in producing dentinal defects.

Key Words: Dental internal fit, dentin, Gutta-percha, root canal obturation, tooth fractures

INTRODUCTION

The root canal system should be sealed three-dimensionally during endodontic therapy. Various methods have been advocated for obturation; however, all the materials and techniques result in some degree of leakage.[1] To prevent leakage and increase tooth strength, it is necessary to create a uniform and void-free obturation from the coronal to the apical of the root canal.

Cold lateral compaction (CLC) is probably the most commonly taught and practiced obturation technique worldwide.[2,3] Some of the technique's disadvantages include lack of Gutta-percha adaptation with the root canal walls, the inability to fill the canal irregularities and a possible lack of uniform density of the filling material.[3] A number of methods have been reported to enhance

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Gutta-percha adaptation and density in the CLC technique.[4-8]

Mechanical lateral compaction (MLC) is an obturation technique described by Gound *et al*.[6] to improve the quality of CLC technique. This technique involves the mechanical activation of finger nickel-titanium (NiTi) spreaders in an endodontic reciprocating handpiece. It is believed that in this variant of CLC, friction between the activated spreader and Gutta-percha may make it soften, increasing spreader penetration and Gutta-percha density and adaptation. Thermal safety, cost-effectiveness, working length control and achieving higher Gutta-percha density are some of the advantages of MLC.[6,9]

Dentinal defects such as cracks and fractures in tooth roots may be one of the adverse effects of root canal obturation.[10] These defects may have the potential to develop root fractures[11] and, therefore, should be prevented. Vertical root fracture is a clinical complication with unfavorable prognosis, resulting in tooth extraction or resection of the affected root.[12]

Studies have examined the effect of various obturation techniques on tooth fracture resistance.[12-17] Spreader penetration depth can be an important factor and an indicator for sealing ability of lateral compaction technique.[18] However, until date, the incidence of dentinal defects during root canal obturation under a safe load with the CLC or MLC techniques has not been compared. The aims of this study were to evaluate and compare the incidence of dentinal defects following CLC and MLC obturation techniques.

MATERIALS AND METHODS

In this *in vitro* study, 110 freshly extracted human mandibular first molars with mature apices were selected measuring 11-15 mm in length from the anatomical apex to the furcation and with 20-40° of curvature[19] in the mesial roots. At first, all the roots were immersed in 5.25% sodium hypochlorite (NaOCl) for 30 min and then observed under a stereomicroscope (HP SMP, 200, USA) at a magnification of ×40 to exclude samples with defects or external resorption.

The coronal portions and distal roots were removed 16 mm above the anatomical apex and perpendicular to tooth long axis with a diamond bur (Teeskavan,Tehran, Iran) and a high-speed handpiece

(NSK Nakanishi Inc., Tokyo, Japan) under water cooling.

One group (*n* = 27) was left unprepared as the negative control (NC). For the remaining 83 roots, straight-line access was created to the mesiobuccal root canal. The working length was established in the mesiobuccal root canals by placing a #10 K-file (Mani, Takanezawa, Japan) in the root canal until it was visible at the apical foramen and subtracting 1 mm from this length. The 12-mm apical portions of all the specimens were embedded in a fresh mix of alginate impression material (Alginoplast, Heraeus Kulzer, Holland) and the remaining coronal portions were coated with self-cured acrylic resin (Meliodent, Bayer Dental, Leverkusen, Germany) as a holding collar. A surveyor was used to position the long axis of each tooth parallel to that of the aluminum holder in order to provide straight-line vertical penetration of the spreader during the test [Figure 1].

Root canal preparation was performed by using Bio-RaCe (FKG Dentaire, La-Chaux-de-Fonds, Switzerland) rotary file sequence according to Debelian and Trope study[20] up to #40/0.04 file. The
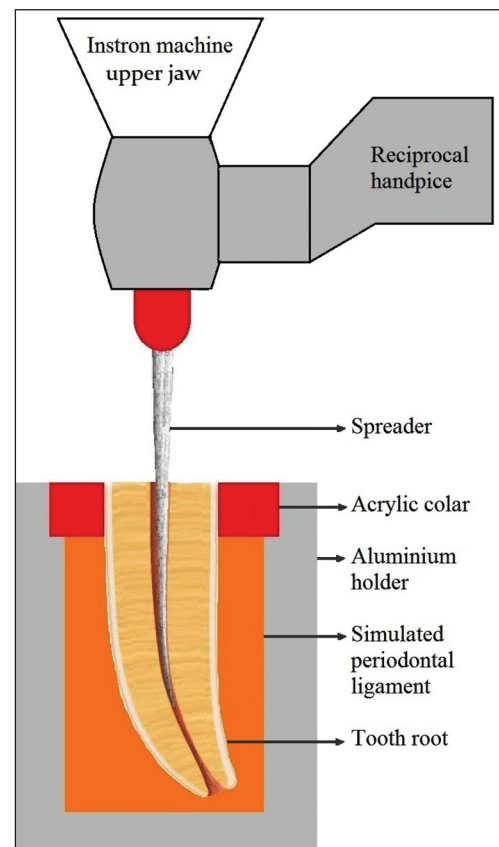

Figure 1: Schematic representation of the experimental setup.

root canals were irrigated with 2.5% NaOCl solution after each file. The root canals were dried with absorbent paper points (Diadent, Seoul, Korea). The remaining 83 roots were then randomly divided into positive control (PC) (*n* = 27), CLC (*n* = 28) and MLC (*n* = 28) groups.

The root canals in the PC group were left unobturated. In the CLC and MLC groups, AH 26 (Dentsply, Konstanz, Germany) was mixed according to the manufacturer's instructions and introduced into the root canal with Gutta-percha cone. Standardized #40 Gutta-percha cones with a 0.02 Taper (Diadent, Seoul, Korea) were placed in the root canals. Gutta-percha compaction was performed with size B NiTi Finger Spreader (Dentsply-Maillefer, Ballaigues, Switzerland). Size MF Gutta-percha cones (Diadent, Seoul, Korea) were used as accessory cones. The spreader was mounted in the Electromechanical Universal Testing Machine (Walter + Bai, Switzerland) by using an Endodontic Reciprocating Handpiece (NSK Nakanishi Inc., Tokyo, Japan). In the MLC group, the spreader was activated during penetration and removal from the root canals. In the CLC group, the spreader was activated only during removal from the root canals in order to prevent gutta-percha removal from the root canals. The obturation procedure was considered to be complete if the spreader could penetrate 9 mm shorter than the working length. The roots with procedural errors such as root perforation or with file separation in the root canal were excluded and replaced with similar roots.

In all the specimens, the electromechanical testing machine was set to apply a load at a speed of 50 mm/min.[21] For the first spreader penetration, the maximum penetration was 1 mm shorter than the working length and during the subsequent spreader penetrations, a maximum of 1.5 kg force was used. The maximum force required for inserting the spreader to within 1 mm of the working length and spreader penetration depth under 1 kg force was recorded by the electromechanical universal testing machine. All the root canal preparation and obturation procedures were performed by one operator.

After obturating all the root canals, the impression material was removed, and the roots were stored for 1-week at 37°C under 100% relative humidity.

All the 110 roots were sectioned perpendicular to their long axis at 1, 3, 6, and 9 mm from the apex using a cutting machine (Isommet Buehler Ltd., Lake Bluff, IL, USA) under water cooling. The slices were viewed under a stereomicroscope at a magnification of ×40 using a cold light source. The appearance of dentinal defects was registered by 2 blinded observers after which pictures were taken with a digital camera (Motic Instruments Inc., Richmond, Canada). To avoid confusing definitions of root defects, two distinct categories were defined: "defect" and "no defect."[12] "No defect" was defined as root dentin devoid of any lines or defects. "Defects" were defined as all the craze lines and partial cracks observed on the slice that either extended from the outer root surface into the dentin or from the root canal lumen to the dentin. In case of discrepancy in the observations of the two examiners, the slices were inspected again and discussed until a consensus was reached. The number of accessory Gutta-percha cones was calculated for each root canal as an indicator for Gutta-percha density.

The *t*-test was used to compare the average depth of spreader penetration and the average force required to insert a spreader to within 1 mm of the working length in the MLC and CLC groups; Chi-square test was used to compare the incidence of defects between 3 and 4 groups. Chi-square test or Fisher's exact test was used to compare the incidence of defects between the two groups; since the number of defects was not distributed normally, they were subjected to statistical analysis using nonparametric Kruskal–Wallis test. Mann–Whitney test was used to compare the mean number of accessory Gutta-percha cones used for obturation in the MLC and CLC groups. The sample size was 28 per group based on a power analysis to meet the constraints of $\alpha = 0.05$ and power = 0.80. Statistical analysis was performed using SPSS/PC 15 (SPSS Inc., Chicago, IL, USA).

RESULTS

The NC group had no defective roots. Defects were found in other groups and were not equally distributed between the 1-, 3-, 6- and 9-mm slices [Table 1]. The differences between the NC group and the other groups in the appearance of defects were significant ($P < 0.001$). The CLC, MLC and PC groups had significantly more defects than the NC group ($P < 0.001$) but were not significantly different from each other ($P = 0.998$). The total number of defective slices in the PC group was less than that in the MLC and CLC groups, but the difference was not statistically significant. The total number of defective

slices in the MLC group was less than that in the CLC group, with no statistically significant difference [Table 2].

The average depth of penetration of a size B NiTi spreader using a standardized 1 kg force was significantly greater in the MLC group than that in the CLC group (*P* < 0.001). The average force required to insert a spreader to within 1 mm of the working length with a master Gutta-percha cone in place was significantly less in the MLC group than that required in the CLC group (*P* < 0.001). The mean number of accessory Gutta-percha cones used for obturation in the MLC group was 11.26% higher than that in the CLC group, but the difference was not statistically significant (*P* = 0.157) [Table 3].

DISCUSSION

The aim of this study was to evaluate the incidence of dentinal defects during root canal obturation with different techniques. Factors such as tooth morphology, trauma, resorptive defects, and dentin

Table 1: Number (%) of defects in the different cross-section slices

Group	1 mm	3 mm	6 mm	9 mm	Total
MLC	4 (14.28)	3 (10.71)	8 (28.60)	7 (25)	22 (19.64)
CLC	5 (17.86)	4 (14.28)	7 (25)	7 (25)	23 (20.53)
PC	4 (14.81)	6 (22.22)	6 (22.22)	1 (3.70)	17 (15.74)
NC	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

CLC: Cold lateral compaction; MLC: Mechanical compaction; NC: Negative control; PC: Positive control.

Table 2: *P* values of statistic analysis between the groups' defects in the different cross-section slices

Groups	1 mm	3 mm	6 mm	9 mm	Total
MLC and NC	0.11	0.24	0.00	0.01	<0.001
MLC and CLC	1.00	1.00	0.74	1.00	0.92
MLC and PC	1.00	0.30	0.59	0.05	0.63
CLC and PC	1.00	1.00	1.00	0.05	0.75
CLC and NC	0.05	0.11	0.01	0.01	<0.001
NC and PC	0.11	0.02	0.02	1.00	<0.001

CLC: Cold lateral compaction; MLC: Mechanical compaction; NC: Negative control; PC: Positive control.

thickness may predispose a tooth to vertical root fractures.[22] However, there are many other factors that may be controlled during endodontic treatment such as access cavity preparation, root canal instrumentation, irrigation and obturation techniques.[23]

The force applied on the spreader is another factor that may predispose a tooth to vertical root fractures and affects spreader penetration. Forces ranging from 1 to 3 kg were applied to spreaders by endodontists.[24] It was shown that root defects could occur with a spreader load as small as 1.5 kg[25,26] and the mesial root of mandibular first molar is weaker than any other tooth except mandibular incisors.[26] In this study, mesial roots of human mandibular first molars were used in order to reproduce clinical situation with a high incidence of dentinal defects.

Thermafil induces significantly less strain than the Obtura or CLC technique.[14] Vertical compaction of Gutta-percha creates wedging forces capable of damaging the root.[15] A study showed that the CLC technique exerted higher vertical forces in comparison to the Thermafil and ProTaper obturation techniques,[17] and Shemesh *et al.*[12,16] reported that root canal preparation and obturation can create dentinal defects on root canal walls; however, the difference was significant between the CLC and noncompaction techniques[12] and was not significant between continuous wave and CLC techniques.[16] Onnink *et al.* reported that root canal preparation, lateral compaction, Ultrafil, and Thermafil resulted in more incomplete fractures compared to the situation in which root canals were not prepared, and the incidence of fracture in the three obturation groups was not significantly different from that in the group which underwent only root canal preparation.[13] This was confirmed by the current study because of the significant increase in the incidence of dentinal defects after preparation alone when compared to the control group which did not undergo any treatment. However, in Onnink *et al.*[13] study the spreader load for the CLC was 3 kg, and Shemesh *et al.* did not determine spreader load in their studies. According

Table 3: Data analysis in obturated groups

Group	AC		1 mm load (kg)		WL — SP (mm)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
MLC	4.25±1.11	3-8	1.508±0.919	0.303-3.869	2.28±1.29	1-4.67
CLC	3.82±0.90	2-6	2.526±1.017	0.767-4.056	3.34±1.37	1-5.98

SD: Standard deviation; CLC: Cold lateral compaction; MLC: Mechanical lateral compaction; AC: Number of accessory Gutta-percha cone to fill canal; 1 mm load: Load for spreader penetration to 1 mm shorter than working length in kg; WL — SP: Working length minus spreader penetration depth in mm with 1 kg load.

to the dentinal defect incidence, this study showed that MLC or CLC with a safe load (≤1.5 kg) may be appropriate techniques for root canal obturation.

Moreover, spreader penetration depth in MLC and CLC obturation techniques was evaluated. A number of factors have been investigated previously in relation to spreader penetration, but no study has ever compared spreader penetration depth in different obturation techniques. NiTi spreaders compared with stainless-steel ones penetrate deeper into the canal,[27] have less potential to create vertical root fractures in curved canals[28] and produce less force on the dentinal wall, but there is no significant difference in microleakage between these spreaders.[29]

According to the results of this study, spreader penetration to within 1 mm of the working length with a force smaller than 1.5 kg were 57% and 25%, and with a force smaller than 1 kg were 36% and 3.6% in the MLC and CLC groups, respectively. The average force required to insert a spreader to within 1 mm of the working length with a master Gutta-percha cone in place was 1508 g in the MLC group and 2526 g in the CLC group. Therefore, it seems MLC technique has more safety and may produce better apical seal than CLC technique.

Dentists use their experience, tactile sense, and spreader penetration depth as load-limiting indicators on spreaders. We found that, in the MLC technique, the maximum force required to insert the spreader to within 1 mm of the working length was significantly different from that in the CLC technique, but our expectation for the difference in the incidence of defects between the MLC and CLC groups was not confirmed by data analysis. In addition, comparison of defects indicated that root canal obturation with the CLC or MLC techniques using a 1.5 kg load cannot significantly increase dentinal defects compare to root canal preparation with rotary instruments. Therefore, root canal preparation with rotary instruments may be more harmful.

Additionally, filling material density can be used for the evaluation of root canal obturation quality. If the number of accessory Gutta-percha cones is an indicator for Gutta-percha density, the current results support the results of other studies,[6,9] indicating that the MLC technique is superior in its ability to produce a denser fill than the CLC technique.

Micro-computed tomography (micro-CT) was used for evaluation of dentinal defects after root canal preparation.[30] It is based on X-ray transmission images, so the presence of Gutta-percha as obturation material or filling with metal compositions may lead to artifacts influencing the micro-CT image data analysis.[31,32] Therefore, in the present study, similar to recent studies which evaluated dentinal defects,[33,34] evaluation was based on root sectioning and direct observation by stereomicroscope. Sectioning and direct observation has some limitations, including the presence of an extended crack in two or more sections which may influence results. However, this drawback has equal effect on all groups.

Storage, mechanical preparation, chemical effect of NaOCl as irrigant and sectioning procedures may have destructive nature on dentin. In this study, storage and sectioning procedures were ruled out considering the NC group. A selection of the PC group was to show the potential damage produced by the mechanical preparation and the chemical attack with NaOCl irrigation.

Prevention of root dehydration[35] and simulation of periodontal ligament (PDL)[36] is essential in the evaluation of crack formation or fracture load information. We used alginate impression material to prevent root dehydration and to simulate PDL. Similar to other artificial PDL reconstructions, this impression material does not have viscoelastic properties similar to PDL.

In vitro studies do not reflect the clinical settings. Therefore, the results of this study should be interpreted with caution, and further clinical studies are required.

Considering the high incidence of dentinal defect following root canal preparation with Bio-RaCe system, recruiting a preparation technique with a lower incidence of dentinal defect in studies which evaluate the safety of obturation technique is recommended.

CONCLUSION

The MLC and CLC techniques were the same in producing dentinal defects. However, the majority of dentinal defects created during root canal preparation. Due to greater spreader penetration and the lower average force required for inserting a spreader to within 1 mm of the working length in the MLC technique, it may be a suitable alternative obturation method.

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