

Evaluation of the quality of three canal obturation techniques: A laboratory study

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Abstract

Introduction: The aim of the present study was to compare the filling capacity of cold lateral condensation, warm vertical condensation and Thermafil[®] in severely curved canals of extracted human molars.

Material and Methods: Mesio Buccal (MB) canals of 90 mandibular molars with angles of curvature ranging between 25° and 35° and radius of 5 to 9 mm curvature were divided into three groups ($n=30$ each). In each group, canals were instrumented with ProTaper[®] and obturated either by cold lateral condensation (L), warm vertical condensation (V) or Thermafil[®] (T). The limit was considered adequate (0-2 mm to the radiologic apex), or with over-obturation or with over-extension. The presence of voids and their location in the canal was also explored and the density was evaluated. Data were analyzed using the Kruskal Wallis test. Differences were significant with a two-sided $\alpha < 0.05$.

Results: The majority of obturations with adequate limit was from group V (66.8%). Group T displayed the highest proportion of over obturation (46.7%) and group L the highest proportion of over-extension (33.3%) ($P < 0.05$). Concerning the density, group T presented the best results in terms of the absence of voids (16.7%) ($P < 0.05$).

Conclusion: Warm vertical condensation and Thermafil[®] techniques give the best results for the obturation of curved canals in respect to limit and density.

Keywords: Apical limit, Cold lateral condensation, Obturation, Thermafil[®], Voids, Warm vertical condensation.

Introduction

Endodontic system obturation is the essential complement of root canal preparation.¹ It must be tridimensional, waterproof and durable in order to maintain the achievements of the steps of debridement and formatting.^{2,3} There are many techniques to that end with their advantages and disadvantages.

Cold lateral condensation is a classical technique still being used due to the malleability of the gutta-percha which is spread and adapted in three dimensions over the already prepared canal walls. It is easy to perform at a relatively low cost.⁴⁻⁶ It has been the technique of choice for a long period of time but its major disadvantage is related to the excess of sealer.

Warm vertical condensation was then proposed as an alternative to improve the results of canal sealing. It uses the thermoplastic properties of the gutta-percha to adapt it to the canal morphology under controlled pressure. Its sealing capability is excellent at a relatively low cost.⁷

The introduction of endodontic continuous motion for root canal shaping led to the creation of new obturation techniques adapted to the resulting shapes.⁸ Thermafil[®] (Dentsply Maillefer, Ballaigues, Switzerland) is one of those modern techniques in which case the obturator is made of a flexible plastic tutor (with standard dimensions) covered by gutta-percha. It contains a gutter that facilitates the partial (canal anchoring) or total (re-treatment) desobturation. It also displays the sink marks. The obturator is heated in an oven prior to its introduction and condensation inside the canal system. The technique is easy to perform and ensures excellent sealing.^{9,10}

The aim of the present study was to compare the filling capacity of cold lateral condensation, warm vertical condensation and Thermafil[®] techniques in severely curved mesio Buccal (MB) canals of extracted human mandibular molars. The null hypothesis was that there is no difference between these techniques with respect to density and limit.

Material and Methods

The study was conducted in the Conservative Dentistry and Endodontics unit, Department of Dentistry, Faculty of Medicine, Pharmacy and Odontology-Stomatology of Cheikh Anta Diop University of Dakar. The experimental protocol was approved by the ethical committee of the Ministry of Health of Senegal. A total of 90 extracted human mandibular molars with intact crowns and curved roots were selected. All molars were collected from three dental offices in Dakar, capital of Senegal. Extractions were indicated for periodontal or orthodontic reasons. The teeth showed no apical resorption or previous treatment.

After debridement of root surfaces, they were cleaned with soap and disinfected with 2.5% sodium hypochlorite (NaOCl) (Septodont, Saint-Maure-Des fossées, France). The teeth were then stored in a saline solution for 15 days. Front and side preoperative anteroposterior radiographs were taken and an endodontic access cavity was prepared on each tooth. After navigation of the MB canals, teeth with apical canal diameter compatible with a #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland), a radius of curvature ranging between 5.0 and 9.0 mm and an angle of

curvature between 25° and 35° (according to Schneider's method), were included.¹¹ Then a #15 K-file was placed in the MB canal and pre-instrumentation radiographs were taken. Radiographic images were amplified on a scale of 13×. Measurements were performed using Adobe Photoshop CS3 (Adobe Systems Inc., San Jose, CA).

The angle of curvature was measured in both buccolingual and mesiodistal directions. A straight line (a) was plotted along the right coronal portion of the canal parallel to the long axis. The point where the canal deviates from this line to initiate the curvature was marked point A. A second line (b) was drawn to connect the apical foramen (point B) to point A. The angle of curvature was the acute angle formed by straight lines (a) and (b) and was measured using Photoshop software (Fig. 1A).

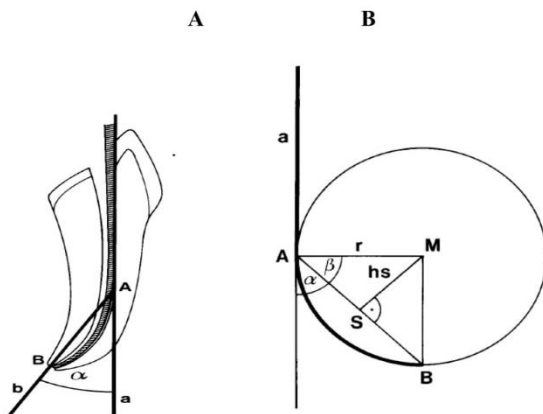


Fig. 1: (A): Measuring the angle of curvature (α) between lines a and b; (B): Calculation of the radius (r) of a curved canal. The root canal is shown as a bold line

The curve between point A and point B is a circular arc, which defines the curved portion of the canal (Fig. 1A and B). The radius of curvature can be calculated based on the measured length of the arc (S) between the points A and B. The arc (S) was measured using a computer program. The radius of curvature was calculated based on the geometrical principles of an isosceles triangle. The formula is as follows: $R = S / 2 \sin \alpha$ where S is the arc between the points A and B and α is the angle of curvature.

The initial working length (WL) was obtained by subtracting 1 mm from the length obtained after the appearance of the tip of a K-file inserted in the canal. This length was verified using radiography with front and side images.

After evaluation of the initial WL, root canal shaping of teeth was carried out, with each tooth maintained in a tooth holder (Protrain, Simit Dental, Montova, Italy). Canal shaping was done with ProTaper® instruments (Dentsply Maillefer, Ballaigues, Switzerland) in a brushing motion starting from S1 file to

reach the initial WL. Then S2, F1 and F2 were used in the WL according to the manufacturer's instructions. The canals were irrigated with 2.5% NaOCl solution and dried using paper cones (DentsplyMaillefer, Ballaigues, Switzerland).

Based on the degree and the radius of curvature, teeth were allocated into three identical groups of 30 teeth each (L, V, and T). The homogeneity of the three groups with respect to the degree and the radius of curvature was assessed using Kruskal Wallis's test.

In Group L, after cleaning and shaping, a finger spreader (Micro-Mega, Besançon, France) with a diameter corresponding to the apical diameter of the prepared canal was chosen so that it reaches the WL. A master cone (DentsplyMaillefer, Ballaigues, Switzerland) was adjusted, sealed and finally compacted at the apical limit of obturation. Cones accessories were added and compacted, one by one as needed to hermetically seal the canal system. An X-Ray was used to visualize the obturation and to determine the cone section by the Machtou heat carrier (Dentsply-Maillefer, Ballaigues, Suisse) heated to red. The last step of the obturation was the vertical compacting using a large diameter of Machtou plugger (Dentsply Maillefer, Ballaigues, Switzerland).

Warm vertical compacting (group V) was carried out in two consecutive steps: a descending phase and an ascending phase. After the choice and trial of Machtou pluggers and master cone, the later one was sealed and compacted during the descending phase until the apical third. Then, during the ascending phase, a cone identical to the master cone was cut in fragments of 3 to 5 mm in length excluding its apical extremity. The fragments were softened, put in place and compacted. This procedure was repeated until the canal was completely filled using the Machtou pluggers of increasing diameters.

In Group T, the prepared canal was explored by an instrument called «Verifier®» (with dimensions equivalent to the tutor not covered by gutta-percha). A control X-Ray ensured the good position of the Verifier® to confirm the right choice of the obturator. The chosen obturator was heated in an oven, the Thermanprep® (Dentsply Maillefer, Ballaigues, Sweden) then inserted into the canal (already dried and covered by a sealing cement) in an apical linear slow but firm motion. Once the WL is reached, the pressure was maintained to compensate for the retraction of the gutta-percha consecutive to the cooling of temperature.

After each canal obturation, a final X-Ray verified the quality of the obturation. The obturation limit was considered adequate if it is located 0-2 mm from the radiologic apex. Under-obturation was considered when the limit was beyond 2 mm from the radiologic apex. Over-obturation referred to a dense sealing with material overflow. Over-extension referred to obturation material overflow with lack of apical sealing. Density was assessed based on the presence of voids in the canal. The

location of existing voids must be précised (coronal third, mid third, and apical third).

During all radiographic procedures, the teeth were placed in a tooth holder. The X-ray tube (Kodak, Paris, France) was oriented perpendicular to the axis of the roots. Radiographs of each root canal were taken from vestibular (clinical) view and mesial or distal (proximal) view. The exposure time was the same for all X-rays with a constant source-film distance of 50 cm and an object-film distance of 5 mm. Radiographic images were recorded in a computer and numbered serially.

Data were analyzed using the Kruskal Wallis test. Differences were significant with a two-sided $\alpha < 0.05$.

Results

Teeth characteristics are summarized in table 1. Canal obturation limit from all different techniques was overall adequate and was estimated overall to occur in 59% of cases. Specifically, most adequate obturations were achieved with the warm vertical condensation in 66.8% of cases. This technique also presented two cases of under-obturation (Table 1).

Thermafil[®] technique was associated with a higher proportion of over-obturation accounting for 46.7% of obturated canals. Cold lateral condensation was associated with a higher proportion of over-extension accounting for 33.3% of obturated canals. The difference between the three techniques of canal obturation was statistically significant with a p-value = 0.0001 (Table 2).

The overall result regarding obturation density showed a void in 59% of obturated canals. The majority of voids were located in the coronal third (41%), followed by the mid third (36%) and the apical third (23%). Overall, warm vertical condensation was associated with the largest proportion of voids (90% of cases). Comparatively, cold lateral condensation was associated with voids in 70% of cases and the lowest proportion of voids was found in the Thermafil[®] group (16.7% of cases). Concerning the location of voids, cold lateral condensation caused more voids to the mid and apical thirds with respectively (26.7% and 23.3% of cases). The difference in density among the three canal obturation techniques was statistically significant with a p-value = 0.0001 (Table 3).

Discussion

In this laboratory study, we compared three canal obturation techniques: Thermafil[®], warm vertical condensation and cold lateral condensation in mesiobuccal canals of 90 mandibular molars. The best outcomes were achieved with the technique of condensation by warm gutta.

The study of root canal shaping and filling in the laboratory was done using experimental models: the resin simulator¹² or extracted teeth.^{13,11,14} The use of resin simulators standardizes the diameter, length, angle and the radius of canal curvature. Thus, variations in human teeth's canals can be eliminated by using resin

simulators. However, human teeth were used in this study for a better representation of clinical conditions. Indeed, resin is different from human dentine in terms of surface texture and hardness. The Knoop hardness value for the resin blocks is 36, whereas for dentine this value is between 40 and 72 according to Patterson.¹⁵ In addition, the major drawback of simulators is the generation of heat caused by the friction of the rotating instruments, which can soften the resin that sticks on the instruments' blade and cause their deformation or breakage. Despite the morphological variations in human teeth, several studies on root canal shaping and filling between different techniques have been carried out on extracted teeth.¹⁶⁻¹⁹ The comparison of the three groups in this study showed good homogeneity between them. There were no statistically significant differences in the radius and angle of curvature between the three groups and a single technique of canal preparation (Protaper[®]) was used for all type of canal obturation. In fact, Protaper[®] allows for an optimal conicity and subsequently a complete obturation of the endocanal system regardless of the used technique.²⁰ Finally, in accordance with the manufacturer recommendations, it was suitable for curved canals used in our study.

The evaluation of the obturation in this study was done by X-Ray. The evaluation of the density and the limit was optimal using two X-Ray views: proximal and vestibulo-lingual. Furthermore, because of the complexity of the endodontic system, many laboratory studies have used this model regardless of the system used for canal shaping and obturation.²¹

In the current endodontic literature, two types of errors are commonly described in the canal preparation, limit and obturation: errors by incompleteness (under obturation) and errors by excess (over-obturation and over-extension).

Under-obturation is defined by a distance between the apical limit of obturation and the radiologic apex beyond 2 mm. Clinical studies show that treatment success of under obturated teeth with preoperative apical lesion drops from 94% to 68% when compared to teeth undergoing complete obturation.²² Chances for success also drop by 14% for each mm lost in the working length for the same teeth. Our findings indicate that warm vertical condensation leads to a higher proportion of under-obturation. This finding is certainly related to the major difficulty of obturating the apical third of a curved canal during the descending phase of the technique.²³ In fact, Matysiak and *al.*²⁴ considers under-obturation as one of the major inconveniences of canal obturation by warm vertical obturation. The lack of sealing of the apical part becomes a concern in presence of a necrotic pulp and/or an established periradicular lesion. For many authors, this inconvenience is significantly correlated with the presence of apical lesions. According to Sjögren²⁵ these under-obturations due to warm vertical condensation are responsible for 6% and 32% of failure based respectively on obturation limit and apical lesion.

In the other hand, over-obturation refers to teeth in which the obturation is beyond the radiologic apex with a good apical sealing. Clinical studies show that over-obtured teeth have a reduced healing prognosis.^{22,26} However, 76% of over-obtured teeth heal perfectly if the treatment is conducted in optimal conditions.²² This is however not a plea in favor of over-obturation because the cement used for root canal obturation and the gutta-percha can be irritating for peri radicular tissue and maintain an inflammatory reaction. Gutta-percha can also act as a foreign body and cause an immune reaction by the presence of giant cells or serve as a matrice for the formation of a bacterial biofilm with germs that are more resistant to the immune defense, especially phagocytosis. However, treatment failure associated with over-obturations often caused by a co-existing intra or extra radicular infection.²⁶ Our findings indicate that Thermafil® is associated with the highest proportion of over obturation. This is explained by the use of a plastic tutor causing a strong pressure to the apex associated with a lateral pressure at the introduction of the obturator into the canal. These two pressures result in a good density often with an over spread of the material in case of permeability of the apex. This inconvenient of Thermafil® system is mentioned by Cantatore²⁷ in a study comparing it with the B system. However, many authors do not consider this inconvenience unfavorable to the success of endodontic treatment.²⁶

Cold lateral condensation was associated with the highest proportion of overextension. This reflects a great number of important anomalies at the apex associated with over-spread of the obturation material. In fact, often, the use of lateral follower in curved canals does not allow for an adaptation of master cones into the apical third, therefore the cone is often pushed beyond the apical foramen due to the lack of sealing at this level.²⁸ Together, these two disadvantages (lack of apical sealing and over-spread of the obturation material) explain why the overextension seriously compromises the chances of success of the endodontic treatment.²⁶

In respect to canal obturation limit, Thermafil® is particularly adapted to curved canals ($p < 0.05$).

In addition to an optimal limit, the goal is to have a homogeneous and dense obturation without voids in the obturation or between the obturation and canal walls.^{29,30} In theory, inadequate density can lead to failure due to micro infiltration through the obturation. Obturation density can be an indicator of the capacity of the obturation to prevent canal infection. Therefore, obturation density and lateral sealing to canal walls are criterions that have been analyzed in many studies.²⁶ Studies that used those criterions considered that the obturation must be dense and homogeneous without voids or spaces between the obturation and canal walls. Many studies found that the less dense and homogeneous the obturation, the worse the impact on the results.^{31,32} Eriksen and Bjertness found that the prevalence of apical parodontitis was higher in obturation with inadequate density, unlike other studies.³³⁻³⁶ Chueh and *al.* and Kirkvang and *al.* showed that dense and homogeneous radicular obturations without voids are highly correlated with a low risk of post-operative pathologies.^{31,34}

Our results show that the technique of cold lateral condensation gives less favorable outcomes in apical and mid thirds where we can locate lateral, secondary and accessory canals. These results are in accordance with results of Brothman indicating that a vertical compacting allows a filling up to twice the number of lateral canal compared to a simple lateral condensation.³⁷ Seemingly, Clark and ElDeeb showed a higher filling rate of lateral canals with Thermafil® compared to simple lateral condensation and Dulac and *al.* showed that Thermafil® allowed the filling of lateral canals at all levels compared to the technique of lateral condensation.^{38,39} Furthermore, the study of Goldberg and *al.* indicated that Thermafil® is the technique associated with the highest rate of canal filling compared to lateral condensation.⁴⁰

Based on the results regarding obturation density, the techniques using warm gutta-percha are more adapted to the tridimensional obturation of curved canals.

Table 1: Teeth characteristics

Techniques	Degree of curvature (degrees)			Radius of curvature (mm)		
	Mean (SD)	Min	Max	Mean(SD)	Min	Max
Cold lateral condensation	31.36 (3.28)	25	35	7.53 (1.09)	5.2	9
Warm vertical condensation	31.38 (3.29)	25.1	35	7.54 (1.1)	5.1	9
Thermafil®	31.36 (3.27)	25	35	7.6 (1.2)	5.2	9
P-value	1.0			1.0		

Table 2: Obturation limit by obturation techniques

Obturation limit	Obturation Techniques						Total	
	T		V		L			
	n	%	n	%	n	%	n	%
Adequate obturation	14	46.7	20	66.8	19	63.4	53	59

Over-obturation	14	46.7	0	0	1	3.3	15	17
Over-extension	2	6.6	8	26.6	10	33.3	20	22
Under-obturation	0	0	2	6.6	0	0	2	2
Total	30	100	30	100	30	100	90	100.0
P	0.0001							

Table 3: Density of obturation by obturation techniques (number and percentage)

Voids	T		V		L		Total	
	n	%	n	%	n	%	n	%
Absence of voids	25	83.3	3	10	9	30	37	41.1
Voidsat coronal third	1	3.3	15	50	6	20	22	24.5
Voidsat mid third	4	13.4	7	23.4	8	26.7	19	21.1
Voidsat apical third	0	0	5	16.6	7	23.3	12	13.3
Total	30	100	30	100	30	100	90	100
P	0.0001							

Conclusion

Our study indicates that techniques of Thermafil® and warm vertical condensation which compact warm gutta-percha give the best results for the obturation of curved canals in respect with limit and density when compared to cold lateral condensation.

However, it is important to note that other factors like a rigorous preparation, a proper sterilization and a waterproof coronal restoration contribute to the success of endodontic treatment.

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