A comparison of apical seal of gutta percha obtained by different compaction techniques. (in vitro study)

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ABSTRACT
Background: To compare the apical seal provided by gutta-percha compacted by three different compaction techniques; these were cold lateral compaction technique, ultrasonic compaction technique, and combination compaction technique.

Materials and methods: Thirty human single canal roots of recently extracted teeth were selected. The teeth were cleaned and their crowns were sectioned at a point approximately 3 mm from the CEJ. The roots were embedded in custom made acrylic socket to facilitate grasping during the obturation procedure. The samples were divided into three groups of ten samples according to the obturation technique used and each sample was radiographed buccolingually and mesiodistally. After storage period of 7 days was ended to allow the sealer to set; the roots were immersed in 2% Methylene blue dye for 48 hours. Then the roots were split longitudinally and the linear measurements of apical dye penetration were made with stereomicroscope.

Results: No Significant differences were found between the different compaction techniques used in the study regarding the linear dye leakage measurements although cold lateral compaction technique showed the highest mean value of dye penetration followed by ultrasonic compaction technique, while the combination compaction technique showed the lowest mean of dye penetration. Therefore, all the techniques have nearly the same apical sealing ability and no technique provide perfect apical seal.

Conclusion: The results of dye leakage measurements showed that all the techniques used in the study have nearly the same apical sealing ability and no technique provide perfect apical seal.

Keywords: Apical leakage, compaction, gutta-percha, ultrasonics.

INTRODUCTION
Root canal treatment can be summarized as a series of procedures for diagnosing pulpal conditions and for cleaning, shaping, and filling the root canal system, so the endodontic treatment consist of phases that are linked and complementary to each other. Failure in any of these will lead to failure of the whole procedure; these phases are diagnosis, preparatory and obturation phase (1, 2).

Obturation, the three-dimensional sealing of the entire root canal system, is the last step in endodontic treatment; the seal has to be perfect to protect the treated surface because while incomplete removal of etiological factors is a major cause of endodontic treatment failure, according to Ingle 59% of failures can be attributing to apical percolation due to inadequate obturation. The role of obturation in root canal treatment, although considered secondary to debridement and disinfection, remains a critical stage for a successful outcome (3).

Ultrasonic instrumentation was introduced to endodontics in 1957, after Richman demonstrated that a modified ultrasonic scaler could be used for root canal debridement and root end preparations.

However, Richman’s ideas and methods did not become popular until 1976 when Martin began his research with the use of ultrasonics for root canal disinfection. (4, 5)

Moreno developed a method for modifying the root canal filling techniques of lateral condensation and vertical condensation of warm gutta-percha. The method used a source of heat from ultrasonic unit (6); he concluded that ultrasonic condensation showed less apical leakage than cold lateral condensation. A photograph of root canal fillings showed a more homogenous filling when ultrasonic technique was used. Ultrasonically activated spreaders have been used to thermoplasticize gutta-percha in a warm lateral condensation technique and have been shown to be superior to conventional lateral condensation in vitro. (7)

Microleakage is a dynamic phenomenon that allows the passage of bacteria, fluids, chemical substances, molecules, and ions between the tooth and the filling. Preventing this phenomenon may increase the clinical success to a rate as high as 96.5% (8). The apical leakage of the endodontic obturation materials and techniques has been measured by degree of penetration of a dye, radioisotope penetration; bacterial penetration, electrochemical means, or scanning electron microscopy. Dye penetration technique is the most frequently method used. (9, 10)
Baumgardner and Krell compared cold lateral condensation of gutta-percha with and without ultrasonic activation of the spreader by using dye penetration method and scanning electron photomicrograph. \(^{11}\) It was concluded that ultrasonically activated spreader group showed least leakage and more consistent, homogenous fill than cold lateral condensation.

The aim of this study was to compare the apical seal provided by gutta-percha compacted by three different compaction techniques; these were cold lateral compaction, ultrasonic compaction, and combination compaction techniques.

**MATERIALS AND METHODS**

**Samples preparation**

Thirty human single canal roots of recently extracted teeth were selected for apical seal comparison; criteria for selection include the existence of straight single canal and root, completely formed apex, a patent apical foramen that is located at the center of the apex of the root, root without cracks or fracture or external resorption (examined by a visible light curing unit). Mandibular central and lateral incisors were excluded from the selection and the size of first file that bound to the working length was #20. The crown of each tooth was sectioned perpendicular to the long axis of the tooth at a point approximately 3 mm coronal to the CEJ. \(^{13}\) The length of roots ranged between 16-18 mm, but care was taken to ensure an even spread of root length throughout the test groups. Each tooth was then placed in a numbered plastic vial containing normal saline solution changed daily.

The teeth were instrumented by step-back technique without using Gates-Glidden. The working length of the root canal was determined and established by passing size 10 K-file (Maillefer / Dentsply, Switzerland) into the root canal until it was visible at the apical foramen; 1 mm was subtracted from this length and considered as the working length. The size of apical preparation was #40 and this was considered as master apical file Flaring began after completion of apical preparation by stepping back each time 1 mm from the working length combined with filing four sizes larger than master apical file, so that the final size reached was #60 for all canals. \(^{14}\) Recapitulation to full working length with master apical file after each flaring file throughout procedure was done to prevent blockage of the canal by debris accumulation at the end of the canal. Irrigation was done with 1 ml of normal saline delivered through a 23-gauge needle placed as far apically as possible into the canal without binding after each size. The canals were then dried with absorbent paper points (Roeko, Germany).

The root of each specimen was wrapped with one thickness of lead foil backing from an X-ray film to the level of the CEJ and lubricated with Vaseline. \(^{15}\) An acrylic resin (ENTA CRYL, Netherlands) mixed according to the manufacturer’s instructions was poured into brass cylindrical moulds lubricated with Vaseline. The root of each specimen was then embedded in a fresh mix of acrylic resin to the level of the CEJ. After the acrylic resin had set, the root was removed along with the lead foil. Silicone impression material (Oranwash VL, Zhermack, Italy) was mixed according to the manufacturer’s instructions and injected by impression syringe into the socket. The root was repositioned in its created acrylic resin socket and excess silicone impression material removed. The space left by removal of the lead foil became a silicone substitute for the periodontal ligament which was approximately 0.15 mm thickness. This made an artificial socket which simulated as nearly as possible the physical condition found in natural tooth socket (figure 1).

**Samples obturation**

A) Cold lateral compaction (Group 1): -

Each sample was placed on the load table of a balance device (Viners, England) during obturation procedure to control the load applied by fingers to the spreader. The range of applied load was 1.5-2 Kg. Two acrylic stoppers were placed under the load table of a balance device in order to prevent applying load over the limit (2 Kg), and this was done for all the samples of the study (figure 2). \(^{17, 18}\)

Dorifill sealer (Dorident – Austria) cement was mixed manually on a clean, dry glass slab. A reamer one size smaller than the master apical file was selected for carrying a small amount of sealer picked up with its tip. The master cone was coated with the sealer and placed into its correct position with in the canal.

A size #40 handled spreader (Union Broach, USA) was used for compaction of gutta percha in the cold lateral compaction technique. The spreader was inserted apically along side the primary gutta percha cone (standardized, ALPHA-
DENT, USA) and displaced laterally to create space for additional cone; the spreader must penetrate apically with in 1-2mm from the estimated working length. When the spreader stopped entering inside the canal it was maintained at this position for 30 seconds and then the spreader was removed from the canal by reciprocation through half an arc and the accessory cone tip (size35 one size smaller than the spreader’s size) dipped in the sealer and inserted into the space left by the spreader. To control rebound of gutta percha, no more than 5 seconds were allowed to elapse between removals of the spreader and placing an accessory cone. The obturation was judged to be complete if a spreader could not penetrate more than 3 mm into the mass of gutta-percha. The excess gutta percha was seared off with a hot instrument and vertical compaction of gutta percha with endodontic handled plugger was done. The coronal 2-3 mm of each tooth was sealed with temporary filling material.

B) Ultrasonic lateral Compaction (Group II)-
A size # 40 ultrasonic spreader (Mectron, Italy) inserted was used for compaction of gutta percha in the ultrasonic technique. Flaring of the canal insured penetration of the spreader with 1-2 mm of the working length. The ultrasonic spreader was inserted into the canal until it was no further penetrated into the canal and activated (at high power setting of endodontic part of ultrasonic device which equal to the degree 5 of the scale of the device, and 10 seconds activation time) with the use of timer. At the termination of the activation, the ultrasonic spreader was left in place for additional 10 second and then removed by reciprocation through half an arc and an accessory cone (size 35) one size smaller than the spreader’s size was placed. To control rebound of gutta percha, no more than 5 seconds were allowed to elapse between removals of the spreader and placing an accessory cone. It was followed by energization with the activated ultrasonic spreader again. During each subsequent energization, the ultrasonic spreader was placed to a slightly more coronal level. The obturation was judged to be complete if a spreader could not penetrate more than 3 mm into the mass of gutta-percha. The excess gutta percha was seared off with a hot instrument and vertical compaction of gutta percha with endodontic handled plugger was done. The coronal 2-3 mm of each tooth was sealed with temporary filling material.

C) Combination of ultrasonic and cold lateral Compaction technique (Group III)-In this technique the same procedure for ultrasonic technique was used except that after removal of the ultrasonic tip, a handled spreader was immediately placed in the canal to the same depth and rotated while pressing laterally against the softened gutta-percha. The spreader was maintained at this position for 30 seconds and then the spreader was removed from the canal by reciprocation through half an arc and an accessory cone (size 35) one size smaller than the spreader’s size was placed in the canal. The process was repeated until the canal was completely filled. The excess gutta percha was seared off with a hot instrument and vertical compaction of gutta percha with endodontic handled plugger was done. Then all the samples were removed from the acrylic socket and radiographed from buccolingual and mesiodistal dimensions and examined by an x-ray specialist who was not aware of the technique used for obturation to determine if the root canals were properly filled.

All obturated roots were wrapped in saline moistened gauze allowing the sealer to set for 7 days with 100% humidity at 37 °C in an incubator.

Leakage study
Each natural tooth was coated with two layers of sticky wax except for the apical 2mm so that tracer could penetrate the canal via the apical region only; 2% freshly prepared Methylene blue dye was used as leakage indicator for all groups. Each tooth was bound to a rubber cap and the apical (3 to 4) mm of each root was left immerse in a plastic vial containing an identical level of 2% Methylene blue dye and placed in an incubator at 37°C for 48 hours. At the end of this period, the teeth were removed from the dye and washed under running water in a position apposite to the apical foramen for one minute; the sticky wax was removed from the teeth surfaces with lacron carver and washed again under running water.

2 kg is the maximum load used.
Longitudinal shallow grooves were made on the buccal and lingual surface without penetrating into the pulp space with a rotating diamond disk (Friadent, Germany) of small diameter under continuous water cooling. Each tooth was split in two halves (Figure 3) by placing the edge of chisel in the groove and applying a gentle pressure. Care was taken to include the apical foramen in the fracture line. Finally, the filling material was removed by grasping it with a pair of tweezers from the coronal side and pulling it laterally. The leakage in all roots was examined. The linear extent of dye penetration from the apical end of the canal preparation to the coronal direction was measured by means of a stereomicroscope (Hamilton, Italy) at 4X magnification with calibrated scale ocular. The maximum dye penetration from both splits of each root was recorded to the nearest 0.1mm, apical leakage were measured independently by two evaluators unaware of the obturation techniques used and the average of the two measurements of each tooth was considered for statistical analysis.

RESULTS

Lateral compaction technique showed the highest mean of dye penetration which was 2.48 mm; followed by ultrasonic compaction technique which showed 1.9 mm mean of dye penetration, while the combination compaction technique showed the lowest mean of dye penetration which was 1.86 mm (Figure 4). ANOVA one way and student's t-test (Table 1&2) showed no significant differences (P>0.05) between the three types of compaction techniques used in the study regarding the dye penetration.

DISCUSSION

In order to evaluate the sealing ability of root fillings, several in vitro methods have been designed. The most common method used to assess leakage remains the measurement of dye penetration. Because of their small molecular size, dye penetration has been used as a dependent measure of sealing ability; however, whether dyes mimic penetration of microorganisms or antigens is still not known. The results of dye penetration studies, however, are confusing and often result in variable conclusions. Many authors questioned the validity of leakage studies and recommended that more research should be devoted to leakage study methodology.

The most common tracer used in apical leakage studies is Methylene blue in different concentrations. Methylene blue is a small molecular weight dye which has high penetration ability which is more than black India ink; its molecular size is similar to that of bacterial by-products such as butyric acid, which can leak out of infected root canals to irritate the periapical tissues. Despite this similarity, the in vitro penetration of dye into canals should not be considered to be directly comparable to the in vivo leakage of irritants out of a canal to cause apical periodontitis. Instead, dye penetration should be considered as an indicator of the potential for leakage. It can also be used to compare two or more techniques and/or materials under the same laboratory test conditions. In this study the choice of the combination of high power setting (5 in the scale of the device) and 10 seconds activation time of ultrasonic spreader in the ultrasonic technique was made depending on the results of two studies made by Bailey et al (2), they gave a recommendation that the combination of high power setting and 10 seconds activation time is the optimum combination for root canal obturation. The size of the spreader used corresponded to the size of MAF according to Ingle (25) that recommended that a spreader of the same apical instrument size or one size larger is chosen so that it reaches to within 1.0 to 2.0 mm but will not penetrate the apical orifice. The size of accessory cones (#35) used was one size smaller than the size of spreader used and this is because of the difficulty in introducing soft gutta-percha cone into space created by the same size rigid spreader. Each sample was placed on the load table of a balance device during obturation procedure to control the load applied by fingers to the spreader. (14) The range of applied load was 1.5-2 Kg so it will be within the acceptable range of 1-3 Kg applied by the dentists during compaction of gutta-percha. (17, 18)

In this study, longitudinal sectioning of roots and direct observation and measurement of dye penetration was used with no demineralization of the sample. The use of Methylene blue was acceptable with this protocol. A 48 hours
immersion period was used. All specimens evaluated in the present study exhibited leakage and this indicates that almost all of these placed root canal fillings failed to produce an apical seal against dye penetration. This may be attributed to the fact that Methylene blue is of small molecular size, and leakage of small molecules in the canal like Methylene blue could not be prevented whatever method of root filling was used.\(^{(26)}\)

No significant differences were found between different compaction techniques used in the study regarding the linear dye leakage measurements although lateral compaction technique showed the highest mean value of dye penetration followed by ultrasonic compaction technique, while the combination compaction technique showed the lowest mean of dye penetration. Although the values for linear dye penetration for all techniques investigated in the study were with in the same range and this was responsible for the non significant results.

These non significant results may be due to the shrinkage of gutta-percha that occur during cooling after heat application and this will cause gap formation between the filling material and canal walls which will be responsible for dye penetration that happened in the warm lateral compaction techniques although the application of heat from ultrasonic spreader lead to better flow of gutta-percha into canal irregularities and give better adaptation initially.

These non significant results among the techniques used in the study may be attributed to the differences in the shape of apical foramen of the samples because it is difficult or even impossible to standardize the shape of it and variations present even with same type of teeth.

The results of this study agree with the results of Luccy et al\(^{(27)}\), they evaluated the quality of the apical seal produced by lateral versus thermomechanical lateral compaction and found no significant difference in leakage.

The findings of our dye leakage study agree with findings of study made by Amidis et al\(^{(12)}\), who assessed four root canal filling techniques including cold lateral compaction and ultrasonic compaction by linear dye penetration measurements. They found relatively small differences among obturation techniques and no significant differences were present between the techniques regarding apical seal ability.

The result of the present study agree with results obtained by Schafer et al\(^{(28)}\) and Gatewood et al\(^{(9)}\), who found non significant difference between warm lateral compaction and cold lateral compaction techniques regarding apical dye penetration.

The results of our study disagree with findings of Baumgardner and Krell\(^{(11)}\) and Al-Dewani et al\(^{(29)}\) who found statistically significant difference in apical dye penetration between ultrasonic compaction technique and cold lateral compaction technique.

![Bar graph representing the mean leakage values in the three groups.](image)

**Table 1: ANOVA test (Analysis of variance of mean) between groups.**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Squares</th>
<th>F</th>
<th>P. Value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2.408</td>
<td>2</td>
<td>1.204</td>
<td>2.36</td>
<td>0.113</td>
<td>NS</td>
</tr>
<tr>
<td>With in Groups</td>
<td>13.760</td>
<td>27</td>
<td>0.510</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>16.168</td>
<td>29</td>
<td></td>
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</tbody>
</table>

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Table 2: Student’s t-test results compare each pair of groups regarding the dye penetration.

<table>
<thead>
<tr>
<th></th>
<th>t-test</th>
<th>P-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic compaction technique (Group II)</td>
<td></td>
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<tr>
<td>VS Lateral compaction technique (Group I).</td>
<td></td>
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<tr>
<td></td>
<td>1.74</td>
<td>0.10</td>
<td>NS</td>
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<tr>
<td>Combination compaction technique (Group III)</td>
<td></td>
<td></td>
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<tr>
<td>VS Lateral compaction technique (Group I).</td>
<td></td>
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<tr>
<td></td>
<td>2.04</td>
<td>0.057</td>
<td>NS</td>
</tr>
<tr>
<td>Combination compaction technique (Group III)</td>
<td></td>
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<tr>
<td>VS Ultrasonic compaction technique (Group II).</td>
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<tr>
<td></td>
<td>0.13</td>
<td>0.90</td>
<td>NS</td>
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</table>

These disagreements may be due to the differences in the methodology for assessing dye penetration used in these studies since both studies used decalcification of samples by clearing technique. The clinical relevance of the results of in vitro dye penetration studies should be interpreted with caution, since it has been shown that root fillings may allow the passage of tracer substances and still be successful, and also dye leakage study usually give conflicting results. (16), (22)

REFERENCES
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