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A study on undergraduate learning of two obturation techniques: Thermafil® versus lateral condensation

Key words *education, filling techniques, lateral condensation, Thermafil*

Introduction: The aim of the present study was to compare two obturation techniques, i.e. Thermafil® and cold lateral condensation, in order to determine which one was most easily and rapidly learnt and applied by dental students.

Methods: Fifty single-rooted teeth were instrumented by the crown-down technique. Five students were requested to obturate five teeth using the Thermafil technique and five using lateral condensation. A microleakage study was performed using a 2% aqueous methylene blue dye solution. The apical portion of teeth was sectioned into six sections and evaluated under a stereomicroscope. The presence of dye microleakage was considered when assessing every section.

Results: Results were processed statistically by frequence of distribution and the Mann-Whitney test. A highly significant difference ($P < 0.0001$) was observed between Thermafil and cold lateral condensation techniques, the former resulting in lower leakage.

Conclusion: The present study, though limited and only referring to a small group, suggested that characteristics of operators and the early repeated use of a technique may influence performance.

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Introduction

Because one of the most common problems in endodontic failures is incomplete obturation[1], many different obturation techniques have been developed in order to increase the success of root canal treatment. Lateral condensation of gutta-percha has been proven to be a very popular and clinically effective filling technique. However, it has been reported that final filling by lateral condensation of gutta-percha resulted in a non-homogeneous mass of several gutta-percha cones pressed together and joined by friction and the cementing substance[2].

Several root canal obturation techniques utilising thermoplasticised gutta-percha or heat-induced compaction of gutta-percha have been designed to produce a more homogeneous canal seal[3,4]. Among them there is a method, first described by Johnson in 1978, who named this technique Thermafil® (Tulsa Dental, Tulsa, OK, USA), to carry thermoplasticised gutta-percha into the root canal space[5]. A number of studies have been performed in the last two decades to assess the differences between the methods of canal sealing, and comparative studies have been performed to determine which gutta-percha technique produced the best adapted root canal filling[6-11]. Warm gutta-percha methods have been shown to reproduce the internal root canal anatomy better than traditional lateral condensation[12-14].

Although alternatives to cold lateral condensation techniques of obturation have been demonstrated in the literature, they are not widely taught in dental schools. Reasons for this conservative policy include the relatively fast execution and simple learning of conventional techniques by undergraduates[15-20] and the fact that post-operative pain prevalence, long-term outcomes and obturation quality are similar between the two techniques, as reported in the most recent meta-analysis of the literature[21].

Although various studies have been conducted to compare the quality of root canal treatment performed by students in different years or endodontics residents[22] and to assess student learning in root canal treatment using new teaching methods[23], no previous data on the different ability to learn two distinct canal obturating techniques are available. In order to understand how obturation techniques such as lateral condensation and Thermafil perform in the hands of novice students, it is necessary to evaluate them under realistic conditions of use. It is also necessary to measure and evaluate such factors as operator differences and the effects of repeated trials on performance.

The aim of the present study is to compare the ability of students to learn two obturation techniques, lateral condensation and Thermafil, assessing if one of the techniques is able to guarantee better results.

Methods

Five subjects, without prior knowledge about obturation techniques, were randomly selected among the third-year undergraduate students in an Italian dental school. A set of four 2-hour lectures about the two obturation techniques, Thermafil and lateral condensation, were given. The lectures were delivered by the same teacher and calibrated to be of a similar length and intensity. After the lectures, students participated in a simulated trial on the two different techniques; they first filled two pre-instrumented clear resin endodontic blocks and then filled 10 pre-instrumented extracted teeth (five for each technique) using Thermafil and lateral condensation. All of the teeth were examined radiographically and assessed by the teacher and the students according to the 'self-assessment' method reported by Manogue et al[22]. Following the experimental model reported by Gulabivala et al[8], students were instructed on the two obturation techniques.

Canal instrumentation

Fifty extracted permanent human teeth, with single, straight root canals with a canal curvature less than than 20 degrees and mature apices, were used in the present study. After extraction, all teeth were placed in 10% formalin. To remove any organic debris, the teeth were stored in 5.25% sodium hypochlorite for 8 h, washed with tap water for 1 h and subsequently stored in saline solution until further use. All of the teeth were instrumented as described below by a clinician well experienced in endodontics. The root canals were prepared using a 'crown-down' technique.

Access to the pulp chamber was obtained using a water-cooled, high-speed tapered diamond bur, and the coronal portion of the root canal was flared using Gates Glidden drills sizes 110, 090, 070, 050 (Dentsply Maillefer, Ballaigues, Switzerland) to provide straight canal access.

A size-10 stainless steel K-file was placed into the root canal until the tip was seen at the apical constriction. This length was recorded, and the working length chosen was 1 mm shorter. A total of 2 ml of 1% sodium hypochlorite was used as an irrigating solution after each file while instrumenting the canals.

The apical portions of the canals were prepared with ProFile® NiTi rotary files 0.04 taper series

(Dentsply Maillefer) at 300 rpm in an ultraslow handpiece and NiTi control motor (Dentsply Maillefer) according to the manufacturer's instructions. Preparation was completed with a ProFile 0.06 taper at 300 rpm. The patency of the apical foramen was maintained by a size 10 stainless steel K-file inserted through the foramen after using each instrument. The final apical diameter, ranging from ISO 30 to ISO 35, was recorded for each tooth, and was chosen to preserve as much as possible the original apex diameter.

All of the 50 teeth were dried by the same operator who prepared the canals, and teeth were allocated randomly to the five students (10 teeth each). Each student performed the obturation of the previously instrumented teeth; five teeth with the lateral condensation technique and five teeth with the Thermafil technique following the sequences described below.

Cold lateral condensation

It was ensured that a medium-fine finger spreader (Dentsply Maillefer) could be placed to within 1 mm from the working length. The sealer (TubliSeal™, SybronEndo, Orange, CA, USA) was mixed according to the manufacturer's instructions and introduced into the root canal by a size 25 ISO stainless-steel R-file. A proper size (either 30 or 35 ISO) standardised gutta-percha cone (master cone) was placed along the working length and the fit was assessed: the master cone should proceed into the canal to the working length, and have a satisfactory tug back. If the cone did not perfectly adapt to the apex, its point was cut until the seal was perfect. It was then compacted into place with the finger spreader. Medium-fine accessory gutta-percha points coated with a thin layer of sealer were added and compacted into place. The process was repeated until the canal was completely obturated. Excess gutta-percha was trimmed using a heated instrument, and the coronal gutta-percha was vertically compacted with a plugger.

Thermafil condensation

The correct size of Thermafil obturator (30 or 35 ISO) was selected by using the Thermafil size verification kit. The sealer (TubliSeal, SybronEndo) was mixed according to the manufacturer's instructions and introduced into the root canal by a size 25 ISO stainless-steel R-file. The Thermafil obturators chosen were placed into a dedicated oven (ThermaPrep®, Dentsply Maillefer) for the time suggested by the manufacturer's instructions. At the end of the heating time Thermafil was inserted to the level previously assessed. The shank of each carrier was cut with a special bur (Therma-Cut, Dentsply Maillefer) while holding the handle of the obturator. The circumferential gutta-percha was condensed vertically.

Micro-infiltration technique

Following obturation, the teeth were stored at room temperature and 100% humidity for 3 days to allow the materials to set. At the end of this period, roots were covered with two layers of nail varnish and sticky wax to within 2 mm of the apex.

The specimens were immersed in a 2% methylene blue dye solution (pH 7.4) for 90 h at 37°C. After removal, they were rinsed with distilled water and dried. The teeth were then embedded in epoxy-resin, sectioned and evaluated as reported in previous similar studies[23].

Six horizontal cross-sections were made at 1-mm intervals along the length of the root in an apical to coronal direction by using a .014 inch diamond saw at approximately 800 rpm under constant irrigation by a cooling liquid (Buhler, USA). All of the sections were then polished using abrasive discs (600 µm and 300 µm grit). They were subsequently mounted on microscope slides, and the upper surface of each consecutive section was recorded by means of a digital camera (Leica, Wetzlar, Germany) connected to a stereomicroscope (Leica MZ12) at 25x magnification and then transferred to the NIH image program for analysis.

Each section was sub-divided into four regions by overlapping a cross frame (Fig 1). The presence of dye microleakage was considered when assessing every section.

Two calibrated examiners other than the operators that treated the teeth were chosen to perform the evaluation of the obturation quality, and an inter-examiner agreement of 80% or more was

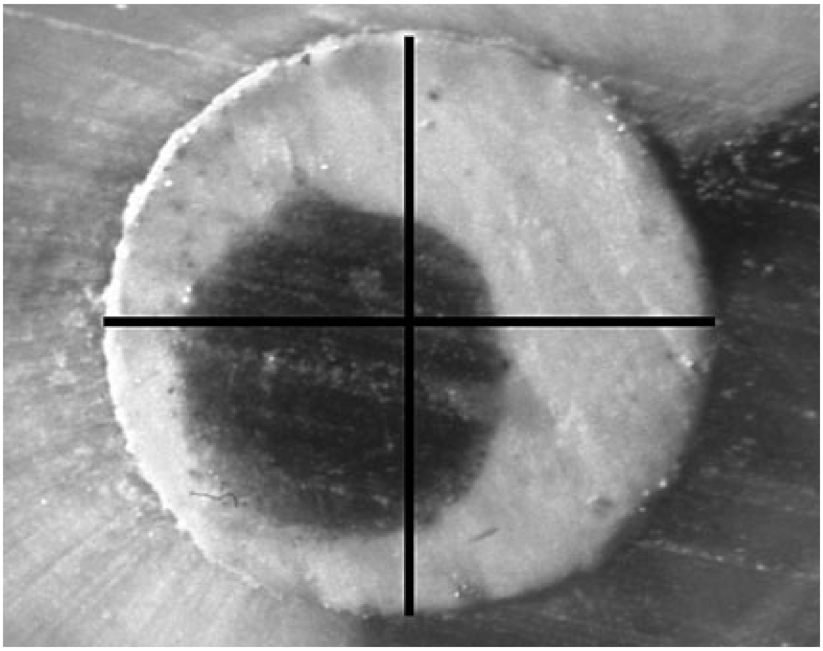


Fig 1 Example of a Thermafil-obturated section to be evaluated and scored. A cross was used to divide the section into 4 regions.

obtained and considered statistically acceptable. Evaluation was blind in relation to the examiners.

The degree of infiltration was assigned using the following categories: A = no dye leakage in any region; B = dye leakage in one region; C = dye leakage in two regions; D = dye leakage in three regions; and E = dye leakage in all four regions. If agreement between the examiners was not achieved, the worst score was chosen (Table 1).

Statistical analysis

The study design involved four factors: technique (2 levels), operator (5 levels), repetitions (5 levels) and tooth sections (6 levels). It was a fully crossed design in which every technique was measured for each operator at each repetition and each section, and each operator was measured at each combination of each of the other factors, etc. The techniques were fixed effects (known by name). Operators were random and repetitions and tooth sections were treated as random in the sense that they represented the entire range of potential measures. Thus, this is a mixed model. A within-subjects design or repeated measures analysis was also necessary.

Frequency distribution and mean values for various combinations of variables were examined to determine the statistical analysis best matching characteristics of the data. Conventional, multi-factorial repeated measures analysis of variance was used. Generalisability analysis, as developed by Cronbach[24], was also used. This method estimates components of variance for each measured main effect in a research study, as well as variation attributable to interactions among factors. These estimates are not affected by the sample-size as are the F-values in traditional ANOVA techniques.

Table 1 Scores obtained by the evaluated samples after the dye leakage test. The degree of infiltration was assigned using the categories A to E.

Technique	A	B	C	D	E
Thermafil (n=137)	52	22	25	23	15
Lateral condensation (n=138)	16	7	17	18	80

A: no dye leakage in any region; B: dye leakage in one region; C: dye leakage in two regions; D: dye leakage in three regions; E: dye leakage in all four regions.

Results

Understanding the data

Preliminary analysis revealed that the dependent variable (number of quadrants in which leakage could be seen) was not normally distributed. An inverted-U distribution appeared (none = 25%, one quadrant = 11%, two quadrants = 14%, three quadrants = 15%, all quadrants = 35%). Collapsing the categories to three produced a more normal distribution (none = 25%, some = 40%, all = 35%). The analysis was carried through with both the five- and three-category divisions of the dependent variable, and similar results were observed. The three-category analysis is reported.

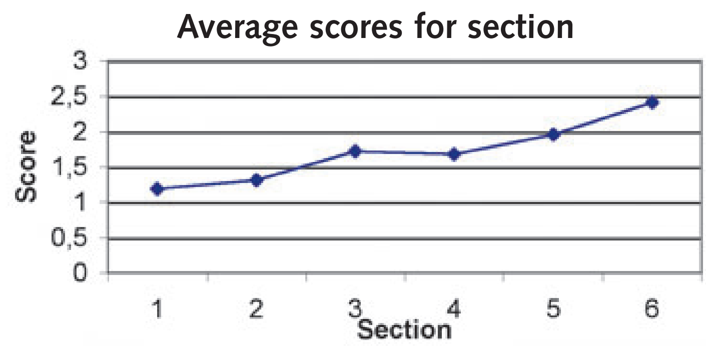
Figure 2 shows that the amount of leakage was greatest in the most apical region and decreased in a uniform fashion as sections were taken more coronally. One-way ANOVA shows that this effect is significant ($F = 7.719$, $df = 5$, $P < .001$). Twenty-three (8%) data points were missing because difficulties in preparing the specimens made some sections unusable. These sections were predominantly in the apical region. A four-factorial ANOVA (technique, operator, repetitions, section) was conducted with computer-interpolated values substituted for missing data. This analysis revealed that there were no significant interaction effects between the section factor and any other factors or their combination. In other words, any conclusion that could be drawn from an analysis without considering tooth section in the present study would remain unchanged if the section factor were retained. All subsequent analyses were collapsed across tooth section.

Analysis of variance

Table 2 displays the three-factorial, 'fully-crossed, repeated measures' ANOVA results. With the expectation of the technique-by-operator interaction, all factors and their combinations contributed statistically significant variance. The largest effect was the difference between techniques (lateral condensation averaging between some leaks, leaks in all quadrants, Thermafil averaging between some leaks and none). There were also significant differences among operators in their average performance. There was a very slight and inconsistent improvement with repetitions (Fig 3) that was significant at the P = .035 level. Among interactions, some operators performed better with lateral condensation while others performed better with the Thermafil technique (Fig 4). This interaction effect was highly significant, $P < .001$. A marginally significant (P = .064) interaction was noted involving operator and repetition. In Figure 5 it can be seen that some operators improved with practice while others got worse. Finally, there is an unusual, but significant three-way interaction (P = .01). This is displayed in Figure 6. In the left-hand graph of the figure, it appears that operators using lateral condensation maintained their relative level of performance (with some fluctuations) throughout the five repetitions. In the right-hand graph, the pattern shows a greater dispersion of performance over time, including two operators whose performance appeared to deteriorate.

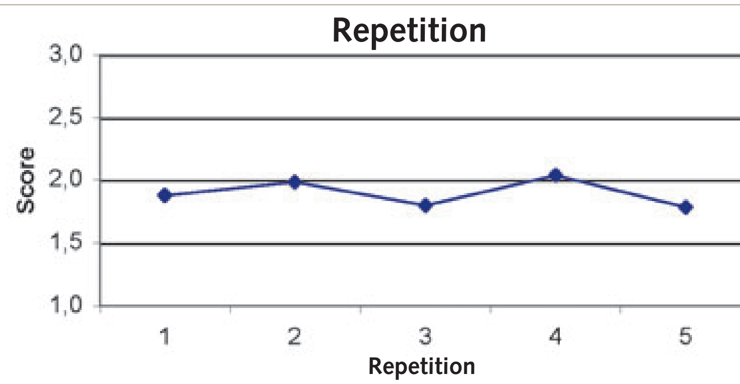
Generalisability analysis

Also shown in Table 2 are the estimated variance components for the present study. These were computed using Cronbach's method and represent the expected variation attributable to each source of variance, correcting for effects of sample



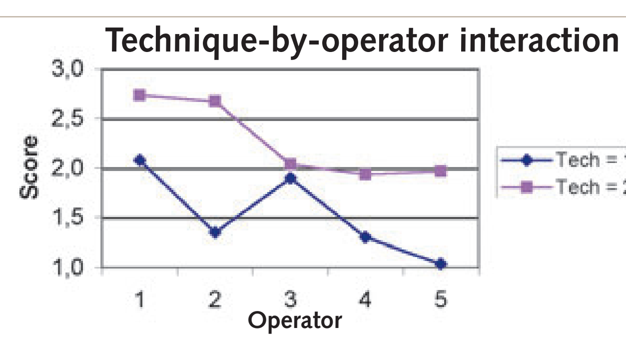
1	2	3	4	5	6
1,1875	1,3125	1,72	1,68	1,96	2,4167

Fig 2 'Section' variance contains variation due to section only (plus random error). There are no interactions. Score = number of quadrants with no leakage. A = 4, E = 0. Section = 1 coronal, 6 apical.



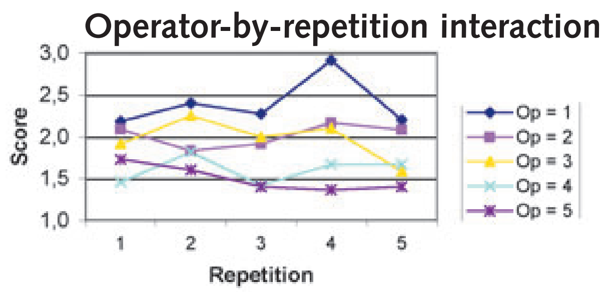
1	2	3	4	5
1,8750	1,9818	1,8000	2,0357	1,7857

Fig 3 'Repetition' variance contains variation due to repetition, operator-by-repetition variance, operator-by-technique-by-repetition interaction (plus random error).



	1	2	3	4	5
Tech = 1	2,0741	1,3448	1,8929	1,3	1,0385
Tech = 2	2,7308	2,6667	2,0357	1,9286	1,9615

Fig 4 'Technique-by-operator' variance contains variation due to technique-by-operator and variance due to technique-by-operator-by-repetition (plus random error).



	1	2	3	4	5
Op = 1	2,1818	2,4000	2,2727	2,9091	2,2000
Op = 2	2,0909	1,8333	1,9167	2,1667	2,0833
Op = 3	1,9167	2,2500	2,0000	2,1000	1,5833
Op = 4	1,4545	1,8182	1,4167	1,6667	1,6667
Op = 5	1,7273	1,6000	1,4000	1,3636	1,4000

Fig 5 "Operator-by-repetition' variance contains variance due to technique-by-operator and variance due to technique-by-operator-by-repetition (plus random error).

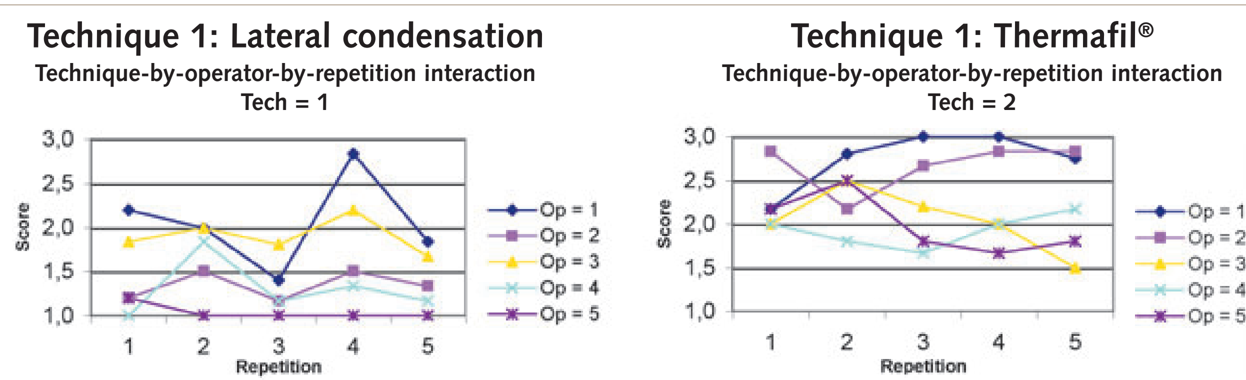
size. These variance estimates are also expressed as a proportion of total variance and are shown in Figure 7. It is evident that differences between the techniques was a major determinant of measured microleakage in this study (42%). Differences between operators and the interaction between operators and techniques are also important factors (18% and 14% respectively). Statistically significant factors, such as repetitions, were relatively unimportant (1%) when placed in context.

■ Discussion

The present study demonstrated that the quality of complete obturation of root canals achieved by novices is governed by multiple factors. A large proportion of the variation in outcomes (42%) could be attributed to the technique used, with Thermafil demonstrating a marked superiority over the lateral condensation procedure. Cold lateral condensed gutta-percha is still the most popular and the most frequently taught technique in dental schools[15-20]. Studies comparing new obturation techniques with cold lateral condensation[9-11] sometimes show the superiority of newer methods.

Lares reported superiority of lateral condensation to Thermafil[6]. Some studies have considered the performance of materials such as Thermafil under various conditions of root curvature[25-29]. However, no research is available which includes other factors besides technique as part of the explanation for performance. In the current study, such additional factors, particularly those involving the operator, combined to account for a larger proportion of the variance than did technique alone.

Differences among novice operators accounted for about half as much variance (18%) as did obturation material. Another significant source of variance (14%) was the interaction between operator and material. One operator seemed to be able to



	1	2	3	4	5
Op = 1	2,2	2	1,4	2,8333	1,8333
Op = 2	1,2	1,5	1,1667	1,5	1,3333
Op = 3	1,8333	2	1,8	2,2	1,667
Op = 4	1	1,8333	1,1667	1,3333	1,1667
Op = 5	1,2	1	1	1	1

	1	2	3	4	5
Op = 1	2,1667	2,8	3	3	2,75
Op = 2	2,8333	2,1667	2,667	2,8333	2,8333
Op = 3	2	2,5	2,2	2	1,5
Op = 4	2	1,8	1,667	2	2,1667
Op = 5	2,1667	2,5	1,8	1,667	1,8

Fig 6 'Technique-by-operator-by-repetition' interaction includes random error.

use either technique equally well; two (one strong operator and one weak operator) were noticeably more successful with Thermafil. Such substantial operator and operator-by-technology interactions were observed by Chambers et al[30] in their study of the fabrication of provisional crowns.

The effects of repetition over five trials for novice operators are complex. This set of procedures represents the first independent performance of students following the initial learning of the two techniques studied. As such, they may be regarded as either learning or early performance. The classical learning curve shows consistent improvement, except for random errors, until asymptote is reached. The five repetitions of the procedures in the present study do not exhibit this pattern. In Figure 3, the overall improvement across repetitions is slight; this source accounts for only 1% of the total variance in the study. More significantly, three of the five operators generally performed worse at the end of the sequence than at the beginning (Fig 5). Finally, as shown in Figure 6, performance across the set was generally constant (except for random variation) for lateral condensation, but some operators improved while using Thermafil while others declined in performance. Such patterns are consistent with an interpretation that factors other than learning may be involved. These might include the multi-step nature of lateral condensation forcing operators to 'pay attention' to their performance throughout. Another factor might be operators forming a self-fulfilling judgment that one or the other technique is superior.

Our analysis did not consider the variable 'gutta-percha extrusion' in the teeth obturated with Thermafil, since this did not occur in any case treated with this technique.

Dye leakage

Camps and Pashley[31] evaluated the reliability of dye penetration studies. They used passive dye application, fluid filtration and volumetric dye leakage tests and did not find any correlation among the results. They concluded that the dye-penetration studies are commonly used because they are easy to accomplish and do not require sophisticated materials, however, they give questionable results.

Table 2 Analysis of variance and estimation of variance components.

Effects	SS	df	MS	F	P	Est var	% var
Technique	38.22	1	38.22	134.87	0.000	1.419	42%
Operator	26.27	4	6.57	23.17	0.000	0.611	18%
Repetition	2.98	4	0.74	2.63	0.035	0.029	1%
T x O	10.82	4	2.71	9.55	0.000	0.481	14%
T x R	1.40	4	0.35	1.23	NS	0.009	0%
O x R	7.37	16	0.46	1.63	0.064	0.230	7%
T x O x R	9.19	16	0.57	2.03	0.013	0.291	9%
Residual	64.62	228	0.28			0.283	8%

T: technique; O: operator; R: repetition

In a more recent study, Karagenç et al[32] compared the results of fluid filtration, electrochemical, bacterial, and dye microleakage tests. They concluded that no correlation between the tests existed (maybe due to the differences in working principles of various test methods and the different nature of obturation materials). Their results, however, raise serious doubts about the information obtained by previous microleakage studies when comparing the sealing ability of endodontic materials.

Although the limits of the dye infiltration techniques are well known, this method was chosen in order to obtain results quickly and to compare the samples based on the same parameters.

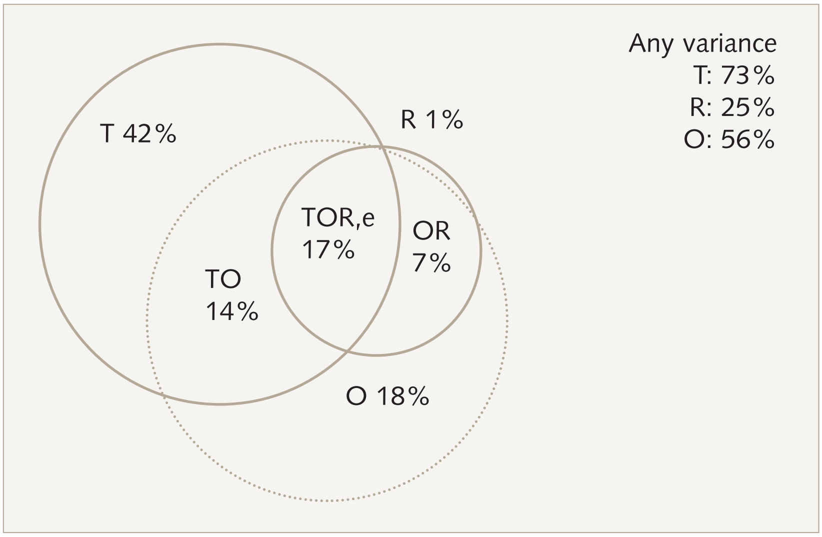


Fig 7 The graph displays the variances as expressions of the total variance.

Conclusion

Classically, research comparing products and procedures is performed by a single experimenter or a small team who perform their work under standardised conditions and maintain a neutral (often experimentally blinded) attitude throughout. Such designs may present a more accurate picture of the techniques being investigated under controlled circumstances. However, such studies do not offer valuable information regarding the way techniques will be introduced and evaluated in actual practice. The present study suggests that the characteristics of operators and their early repeated use of the technique may be important factors in determining performance and may interact with the techniques themselves.

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