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An *ex vivo* comparison of three different gutta-percha cones when compacted at different temperatures: rheological considerations in relation to the filling of lateral canals

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Abstract

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Aim To compare *ex vivo* the penetration of three brands of gutta-percha cones, compacted under a constant force and heated to different temperatures, into artificial lateral canals.

Methodology Resin blocks with simulated main canals, each having two lateral canals (C at 6.5 and A at 13 mm from the surface of the resin block), were selected. A gutta-percha cone, either Mynol MF, Hygenic MF or GT Tulsa 0.04 was compacted into each main canal for 5 s using a wire rod with a diameter of 0.7 mm soldered to the bottom of a metal cylinder, with a force of 2.7 kg at controlled temperatures of 37, 42, 47, 52, 60 °C. The penetration of each brand of gutta-percha into 60 lateral canals (10 at each temperature) was measured using a stereomicroscope. Statistical analysis was performed using the ANOVA, the Scheffè test and the *t*-test.

Results None of the three brands of cones entered up to 0.1 mm within either lateral canal until a temperature of 47 °C was reached; at that temperature only Mynol cones ($P \leq 0.05$) penetrated in four of 10 A-level canals (mean 0.13 ± 0.19 mm) and in all 10 C-level canals (mean 0.43 ± 0.12 mm). The A-level lateral canals were penetrated at 52 °C by Mynol cones (mean 0.76 ± 0.34 mm) to a significantly greater distance ($P \leq 0.05$) than Tulsa cones (mean 0.31 ± 0.12 mm) and Hygenic cones (mean 0.11 ± 0.08 mm). At 60 °C the Mynol cones (mean 1.93 ± 0.34 mm) penetrated significantly more ($P \leq 0.05$) than the Tulsa cones (mean 0.86 ± 0.22 mm) and Hygenic cones (mean 0.67 ± 0.19 mm). The C-level lateral canals were penetrated at 52 °C by Mynol cones (mean 0.91 ± 0.29 mm) to a significantly greater distance ($P \leq 0.05$) than Tulsa cones (mean 0.47 ± 0.16 mm) and Hygenic cones (mean 0.46 ± 0.15 mm), whilst no significant difference was found at 60 °C.

Conclusions When heated and compacted, the three gutta-percha cones penetrated the lateral canals to different degrees. They penetrated more than 0.43 mm into the lateral canals only at temperatures higher than 47 °C.

Keywords: filling technique, gutta-percha, temperature.

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Introduction

Gutta-percha in combination with a root canal sealer is the most commonly used filling material. The sealer fills the minor irregularities (Hata *et al.* 1992) and acts as a lute between the gutta-percha and canal wall (Najar *et al.* 2003). Some sealers shrink upon setting, whilst others are susceptible to decomposition (Peters 1986, Kontakiotis *et al.* 1997). The amount of sealer should be restricted to a thin layer between the gutta-percha and the walls of the canal (Peters 1986, Wu *et al.* 2000), but it should be sufficient to restrict the passage of microorganisms and their by-products that are responsible for periradicular disease (Kersten & Moorer 1989, Gutmann & Witherspoon 2002).

Gutta-percha is a thermoplastic polymer material within which segments of the polymer molecules may be sufficiently aligned and associated to form crystalline segments randomly dispersed among the rest of the disordered, amorphous volume (Bunn 1941, Fisher 1952). Employing X-ray methods, the degree of crystallinity of gutta-percha was reported to be 55–60% (Goppel & Arlman 1948). The crystal structure of pure gutta-percha has been reported in detail (Bunn 1941, Fisher 1952) and it is known that the application of heat or mechanical energy will increase the mobility of the long molecules, perhaps increasing the size of some of the ordered, crystalline segments but, in general, increasing the proportion of the disordered, amorphous volume (Smith 1977).

With lateral condensation, cold (in a more crystalline state) gutta-percha is used. Alternative techniques have introduced the use of applied or frictional heat to plasticize gutta-percha, allowing for better adaptation to canal walls and a higher degree of homogeneity (Schilder 1967, McSpadden 1980, Buchanan 1996). However, these techniques use warm gutta-percha in different ways. It has been stated that heating and compaction may be performed to a distance of 5–7 mm from the end-point of the gutta-percha when using the warm vertical condensation technique (Marlin & Schilder 1973), that a temperature increase to 40–42 °C usually occurs in the apical gutta-percha, and that it should not exceed 45 °C to avoid the volume variations dependent on phase changes (Goodman *et al.* 1981). In contrast, when using Thermafil obturators (Dentsply Maillefer, Ballaigues, Switzerland), thermomechanical compaction (McSpadden 1980) and the Obtura II System (Obtura Corp., Fenton, MO, USA), gutta-percha is heated to higher temperatures, increasing the proportion of the amorphous phase as happens with all semicrystalline thermopolymers (Smith 1977).

To add to this complexity, the available commercial gutta-percha products vary greatly in their composition (Combe *et al.* 2001, Gurgel-Filho *et al.* 2003) although not all have been chemically or physically analysed (Friedman *et al.* 1977, Marciano & Michailesco 1989). It has been reported that the proportions of organic (gutta-percha polymer and wax/resins) and inorganic (zinc oxide and metal sulphates) components used in commercially available endodontic points have substantial influence on their thermomechanical properties (Friedman *et al.* 1977, Tagger & Gold 1988, Marciano & Michailesco 1989). This may lead to variations in brittleness, stiffness, tensile strength, and also in flow, plasticity, elongation, inherent tension force, and thermal behaviour (Friedman *et al.* 1977, Tagger & Gold 1988).

Previous studies, comparing the effectiveness of filling techniques, have given conflicting results. Some (Peters 1986, Beer *et al.* 1987, Jacobsen & Begole 1992, Liewehr *et al.* 1993) reported that none of the techniques studied provided a superior seal whilst other studies reported better filling of lateral canals (Brothman 1981, Clark & ElDeeb 1993, Goldberg *et al.* 2001) and better outcomes from treatments using warm gutta-percha (Farzaneh *et al.* 2004).

Lateral condensation has proven to be a clinically effective filling technique, is widely used by practitioners, and is still the standard to which all other techniques are compared (Ingle & Bakland 2002). Nevertheless, some studies report the creation of voids, spreader tracts, excessive volume of sealer, and lack of surface adaptation to canal walls (Brayton *et al.* 1973, Eguchi *et al.* 1985).

The consequences of compression of gutta-percha within a root canal will differ with the taper of the canal, the physical composition of the gutta-percha, the point of application of the compacting force, and the temperature. Cold gutta-percha, with a large proportion of crystalline segments, is much less malleable than warm gutta-percha that has a much lower proportion of crystalline segments. Subjected to stress, its elastic deformation may be reversible until the yield strength is exceeded (Telli *et al.* 1999). Beyond the yield strength the plastic deformation remains after the stress ends. In contrast, gutta-percha with a much lower proportion of crystalline segments, 'in the amorphous state', will have much less elastic (reversible) deformation and may be considered as a non-Newtonian fluid of high viscosity that deforms continuously to flow under a shearing (tangential) stress.

The issues discussed above suggest the need to examine and define the rheological responses of different gutta-percha products at different temperatures, and to define their chemical and physical characteristics, in order to provide clinicians with objective data that can be used to improve the quality of root filling.

A variety of previous studies (Wolcott *et al.* 1997, DuLac *et al.* 1999, Silver *et al.* 1999, Goldberg *et al.* 2001) evaluated the flow of gutta-percha into lateral canals as a test of the ability of the material to effectively fill irregular spaces. However, there is limited evidence available on the behaviour of different gutta-percha compounds, at controlled and known temperatures, compacted under a known constant force.

The purpose of this study was to compare the penetration into artificial lateral canals, branching from a standard root canal, of three brands of gutta-percha cones when heated to different controlled temperatures and compacted under a fixed force.

Materials and methods

Specimens preparation

Sixty Thermafil (Dentsply Maillefer) training blocks (Fig. 1), each with four simulated main canals, were selected. Two parallel lateral canals, with nominal diameter of 0.5 mm, branched from each main canal, at right angles from the main canal axis. The most coronal, at 6.5 mm from the surface of the resin block, was labelled C; the other was a further 6.5 mm more apical than C (Fig. 1) and was labelled A. Both lateral canals consisted of three cylindric sections that were measured using a stereomicroscope (Zeiss Stemi 2000-C; Carl Zeiss Jena GmbH, Zeiss Group, Jena, Germany) equipped with a calibrated micrometer grid: the inner section had a diameter of 0.5 mm, and length 0.2 mm (A) and 1 mm (C); the middle section had a diameter of 0.7 mm, and length 1 mm (A) and 1 mm (C); the outer section had a diameter of 1 mm, and length 2 mm (A) and 2 mm (C). The length of each main canal was 18 mm from the surface of the resin block, its diameter at the orifice (3 mm from the surface of the resin block) was 1 mm, its diameter at the end point was 0.3 mm and its taper was 0.04. The curvature was 25° when measured with the method of Schneider (1971). The patency of all the main and lateral canals was verified using a size 20 stainless steel K-file (Dentsply Maillefer).

Three brands of commercial gutta-percha cones were compared: (i) Mynol MF (Mynol, Block Drug Corporation, Jersey City, NJ, USA); (ii) Hygenic MF (Hygenic, Akron, OH, USA); and (iii) GT Tulsa 0.04 (Dentsply Tulsa Dental, Johnson City, TN, USA). Three cones, one from each of the three brands, were inserted into three of the four main canals of each of the 60 training blocks. Each cone was cut 0.5 mm short of the working length. After insertion, each cone was cut 3.5 mm from the external surface of the resin block, i.e. at 3 mm from the lateral canal C. Thus, 60 canals were filled with each brand of cone.

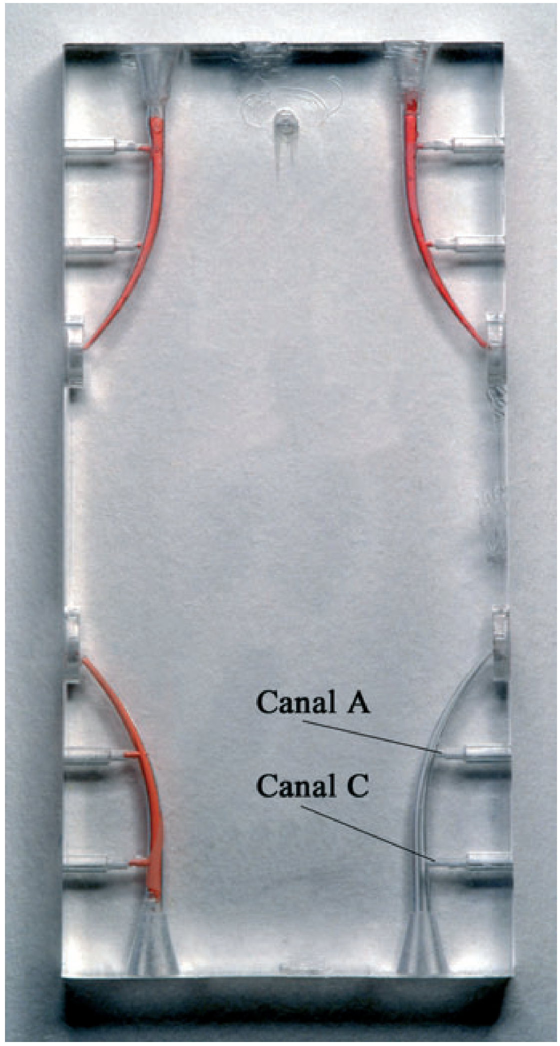

Figure 1 The simulated canals after compaction of gutta-percha.

The compactor

Two short stainless steel wires were soldered to the bottom of a metallic cylinder to serve as compactors (Fig. 2). One was 9-mm long and 0.7 mm in diameter; the other was 11-mm long and 0.5 mm in diameter. The cylinder weighed 2.7 kg and could be moved up and down on a vertical bar fixed on a metal base (Fig. 2). The weight was selected to provide a compacting force that did not exceed 3 kg (Blum *et al.* 1997). A preliminary test was performed to ascertain

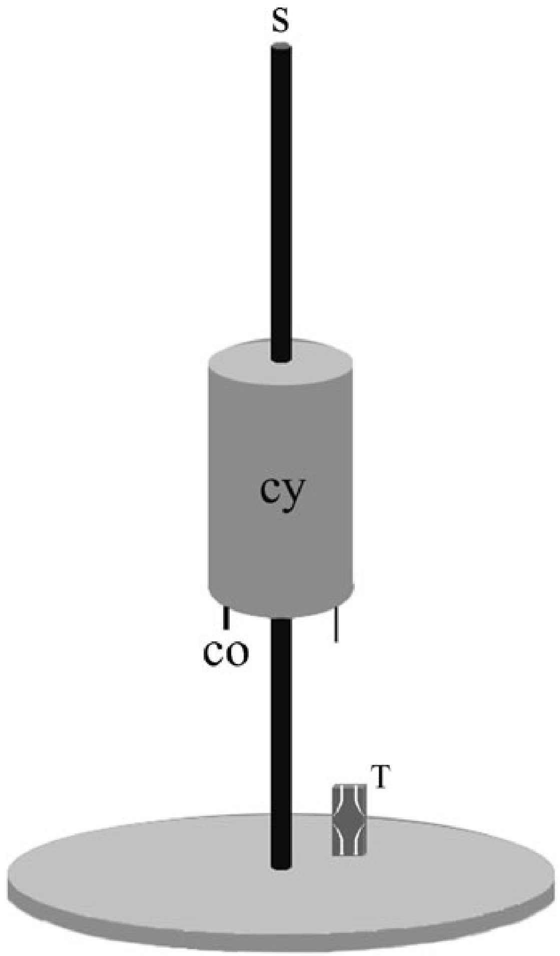

Figure 2 The device used to compact the gutta-percha cones. cy, cylinder; s, shaft; co, compactor tip; T, training block with simulated canals.

that the resin blocks were hard enough to withstand the weight of 2.7 kg used without visible scratches, deformation or fracture.

This device and all the training blocks were immersed into a thermostatic bath at a controlled temperature of 20 °C for 30 min. Then 30 gutta-percha cones, 10 of each brand, were compacted. The compaction was effected by lifting the cylinder on the vertical bar sufficiently to insert the shorter rod into a coronal orifice on a resin block. Then the 2.7-kg weight of the compactor was allowed to bear upon the gutta-percha cone for 5 s. After compaction, the 10 training blocks were removed from the bath and dried. The same procedure was repeated with groups of 10 training blocks at increasing levels of temperature at 37, 42, 47, 52 and 60 °C. When, at the highest temperatures, the gutta-percha began to melt, the compacting force resulting in tip of the rod penetrating the gutta-percha. However, the compacting tip did not penetrate more than 6 mm into the coronal orifice, and only the rod with an 0.7 mm apical diameter was used.

The movement of the gutta-percha into the lateral canals was evaluated using a stereomicroscope (Carl Zeiss Jena GmbH) equipped with the calibrated micrometer grid; the deepest point of penetration into each of the two accessory canals, A and C (Fig. 1) at each temperature was measured.

Statistical analysis

The ANOVA and the *post hoc* Scheffè test were used to analyse the effects of temperature increases on the mean depth of penetration of gutta-percha into the lateral canals using three brands of gutta-percha cones. The *t*-test was used to analyse separately the effects of the different temperatures on the mean deepness of penetration into the lateral canals A and C.

Results

The mean values and SDs of the mean depth of penetration of gutta-percha into canals A and C by the three brands of gutta-percha at the increasing temperatures are shown in Table 1. No penetration into the lateral canals was observed at 20 °C (control group). With one exception, none of the three brands of cones entered up to 0.1 mm in either lateral canal until a temperature of 52 °C was reached. The exception, Mynol MF, penetrated the canals at 47 °C in four of 10 A-level canals (mean 0.13 ± 0.19 mm), and all 10 C-level canals (mean 0.43 ± 0.12 mm), in both cases with a significant difference from both Hygenic and Tulsa cones ($P \leq 0.05$).

At a temperature of 52 °C, the gutta-percha of all the three brands of cones entered all the lateral canals for at least 0.3 mm, with the exception of Hygenic cones in the A-level canals when mean penetration was 0.11 ± 0.08 mm (a significant difference from all the other temperatures, $P \leq 0.05$) and occurred only in seven of 10 lateral canals. After a temperature rise to 60 °C, all the three brands of gutta-percha entered all the lateral canals for at least 0.6 mm, with a significant difference ($P \leq 0.05$) in the extent of penetration compared with the other temperatures. At 52 and 60 °C the penetration of

Table 1 Mean values and SDs of the mean depth of penetration of gutta-percha into canals A and C by the three brands of gutta-percha at the increasing temperatures

Cone brand and lateral canals	Temperature (°C)	Lateral canals (*n*)	Mean (mm)	SD (mm)	*P*-value
Tulsa A	20	10	0.0000	0.00000	
	37	10	0.0000	0.00000	
	42	10	0.0290	0.09171	
	47	10	0.0000	0.00000	
	52	10	0.3100	0.12083	$P \leq 0.05$ vs. all the other temperatures
	60	10	0.8570	0.21833	$P \leq 0.05$ vs. all the other temperatures
Tulsa C	20	10	0.0000	0.00000	
	37	10	0.0000	0.00000	
	42	10	0.0240	0.07589	
	47	10	0.0000	0.00000	
	52	10	0.4690	0.15800	$P \leq 0.05$ vs. all the other temperatures
	60	10	0.7550	0.16642	$P \leq 0.05$ vs. all the other temperatures
Hygenic A	20	10	0.0000	0.00000	
	37	10	0.0000	0.00000	
	42	10	0.0000	0.00000	
	47	10	0.0640	0.13235	
	52	10	0.1120	0.08297	
	60	10	0.6720	0.19367	$P \leq 0.05$ vs. all the other temperatures
Hygenic C	20	10	0.0000	0.00000	
	37	10	0.0000	0.00000	
	42	10	0.0000	0.00000	
	47	10	0.0340	0.05797	
	52	10	0.4610	0.15474	$P \leq 0.05$ vs. all the other temperatures
	60	10	1.2420	0.34016	$P \leq 0.05$ vs. all the other temperatures
Mynol A	20	10	0.0000	0.00000	
	37	10	0.0000	0.00000	
	42	10	0.0570	0.09546	
	47	10	0.1360	0.19506	
	52	10	0.7650	0.34222	$P \leq 0.05$ vs. all the other temperatures
	60	10	1.9340	0.34513	$P \leq 0.05$ vs. all other temperatures
Mynol C	20	10	0.0000	0.00000	
	37	10	0.0830	0.09452	
	42	10	0.0300	0.09487	
	47	10	0.4330	0.12437	
	52	10	0.9110	0.29126	$P \leq 0.05$ vs. all the other temperatures, except for 47 °C
	60	10	2.8990	0.72456	$P \leq 0.05$ vs. all the other temperatures

Mynol gutta-percha was always greater than the other cones ($P \leq 0.05$ both at C-level and at A-level at 52 °C, and at A-level at 60 °C). With all three brands of cones, both at A-level or C-level, the penetration was always greater at 60 °C than at 52 °C ($P \leq 0.05$). At 52 °C and at 60 °C, Hygenic cones penetrated less at the A-level cones than Tulsa cones, but without significant differences.

At 52 °C, in the C-level cones, Hygenic and Tulsa cones penetrated equally, whilst at 60 °C Tulsa cones penetrated less than Hygenic cones, but without significant differences.

Only at 60 °C with Mynol cones at A-level and C-level, and with Hygenic cones at C-level, the penetration was more than 1 mm.

Discussion

Conventional lateral condensation of gutta-percha involves compaction without the application of heat (Allison *et al.* 1981). However cold gutta-percha cannot flow. When a compaction force is applied on cold gutta-percha, the relationship between stress (Mpa) and deformation (%) can be represented by a curve (Camps *et al.* 1996). The first part of the curve is straight: there is a linear relationship between stress and deformation. The coefficient is the Young's modulus in Mpa. The point beyond which a permanent deformation occurs is the yield strength. Below this point the deformation is reversible, and the material behaves in a rubbery manner. The percentage of deformation is the loss of length in percentage, necessary to reach a permanent deformation. The cold gutta-percha presents a high yield strength and a small percentage of deformation, whilst warm gutta-percha, on the contrary, presents a small yield strength and a high percentage of deformation (Camps *et al.* 1996). When cold lateral condensation is used, the spreader induces both elastic and plastic strain (Camps *et al.* 1996). But when the spreader has been retracted to allow the insertion of accessory cones, the reversible elastic strain obviously vanishes. With lateral condensation the adaptation of the gutta-percha cones might ultimately be due to plastic strain, that is however, very small at body temperature and mainly occurs close to the point where the force is applied.

The most important property of gutta-percha, as used in endodontics, is its capacity to soften when heated and to be compacted under pressure (Schilder 1967, Schilder *et al.* 1974, Marciano & Michailesco 1989, Camps *et al.* 1996). Techniques such as Thermafil (Dentsply Maillefer), the Obtura System (Obtura Corp.) and thermomechanical condensation (McSpadden 1980) heat the gutta-percha to increase the proportion of the amorphous phase, which may then be considered as a high viscosity fluid.

The proportion of crystalline segments in 'amorphous' gutta-percha can be sufficient to allow some deforming stress without flowing. Once the yield point is exceeded the viscous flow provides permanent 'plastic' deformation; this behaviour is called 'plasticity'. The plasticity of gutta-percha depends on the proportion of the amorphous phase, hence on the type or brand of gutta-percha, and on the temperature.

The compacting of heated amorphous gutta-percha is difficult to control, especially close to the apex (Clinton & Van Himel 2001). The main difficulty for the practitioner is to adjust the compacting procedure to the softening of the gutta-percha.

When gutta-percha is compacted at body temperature, where it is not plasticized, the rheological response is different than at higher temperatures where it is plasticized. In the present study, the gutta-percha of all three brands did not consistently enter either lateral canal, until a temperature of 52 °C was reached. However, Mynol cones did penetrate at 47 °C to an average of 0.1 mm into canal A and 0.4 mm into canal C.

A plastic mass of gutta-percha forced to flow will deform on contact with the internal surface of the root canal. A compacting force applied to gutta-percha can always be resolved into two vectorial components: a tangential force, directed towards the apex and parallel to the surface of the canal wall, and another force at right angles to the same surface. Any frictional force that would reduce the forward motion of the penetrating gutta-percha, would likewise be parallel to the canal wall. Plasticized amorphous gutta-percha is easily deformed, and the force normal to the wall and the frictional force are both small and there is no elastic strain. Thus, when compacting heated amorphous gutta-percha the major force is directed towards the apex and the flowing gutta-percha may extrude, if apical patency has been maintained during instrumentation. Extrusion has been reported to be a complication of thermo-softened techniques (Clinton & Van Himel 2001, Gilhooly *et al.* 2001). In addition, the small force normal to the canal wall may prevent a closer approximation between gutta-percha and the dentine surface.

Because of its plasticity, amorphous gutta-percha may fill irregular spaces, but some negative effects have also to be taken into account. The temperature increase, required to produce the flow under stress, also leads to an increase in volume and the need to compact the cooling gutta-percha to avoid shrinkage.

The three types of gutta-percha cones used in this study plasticized at different temperatures and behaved differently when compacted. Mynol cones showed significantly less stiffness and plasticized at a lower temperature than Hygenic and Tulsa cones. Accordingly, it is questionable whether optimal three-dimensional filling may be realized with different techniques and different gutta-percha products without knowledge of the physical phenomena involved.

Another associated problem is the difficulty of predicting the distribution of amorphous gutta-percha within all the branches of a complex root canal system. The distribution depends on the applied force, the viscosity of the compacted gutta-percha, the diameters and the tapers of the main and the accessory canals, and the angles between them. The apical accessory canals often have smaller diameters than the main canal (Kasahara *et al.* 1990, Miyashita *et al.* 1997). Under compaction the flowing gutta-percha mainly moves where the resistance is least. When apex patency is maintained, extrusion through the apex could occur more easily than penetration into the narrow lateral canals.

Warm vertical compaction (Schilder 1967) and the 'continuous wave technique' (Buchanan 1996) offer techniques that use the apical control of the internal placement of a cold point whilst providing the homogeneous, three-dimensional filling advantages of the thermo-softened techniques. Warm vertical compaction was claimed by Schilder (1967) to routinely fill accessory canals in the cervical and middle thirds (with gutta-percha and sealer), as well as in the apical deltas (mostly with cement), ensuring at the same time accuracy in positioning the apical end of the filling at the working length.

Marlin & Schilder (1973) reported that a temperature increase of 4–5 °C above body temperature of the apical gutta-percha, and compaction at a distance of 5–7 mm to the apex, were adequate to ensure good adaptation. At those temperatures, in the present study no penetration into A or C canals occurred, therefore ruling out that either observable gutta-percha plastic strain or flow may take place with such limited heating. There was a distance of 6.5 mm between the A and C lateral canals in the simulated canals, and the greatest penetration of the compactor was 6 mm from the coronal orifice that is at a distance of 1–7 mm to either A or C, i.e. within the limits advocated by Marlin & Schilder (1973).

It must be emphasized that the accessory lateral canals had 0.5-mm diameters, and offered limited resistance to the flow of gutta-percha. Despite this small resistance, only at temperatures exceeding 60 °C did the gutta-percha penetrate more than 1.2 mm into the lateral canals, and only then in three cases: with Mynol cones at levels C and A, and with Hygenic cones at level C. At 52 °C the penetration was always <1 mm. In addition, other studies (Venturi *et al.* 2002, Villegas *et al.* 2005) recorded inconsistent apical temperature increases when a heated tip was pushed to within 0.5–4 mm of the apex. Therefore, the available data indicates that gutta-percha might become plasticized by the Schilder technique and flow to fill irregular spaces only in the coronal and middle thirds, where Marlin & Schilder (1973) recorded temperatures up to 80 °C, whilst a more crystalline state is maintained in the apical third.

During the filling of the simulated canals in resin blocks, due to their composition, thermal conductivity and diffusivity could have interfered by conducting heat away from the warmed gutta-percha and having repercussions on the developed forces. Blum *et al.* (1998) reported that the results of warm vertical condensation using natural teeth showed that the values for the horizontal and vertical forces were not significantly different from those for a simulated metallic root canal (that is more conductive than a simulated resin canal), and that this might be due to the fact that gutta-percha is a poor thermal conductor (Schilder 1967).

From a rheological viewpoint, when apical patency has been maintained, heating and compacting of gutta-percha in the middle and coronal thirds must differ from the same procedures in the apical third of a root canal. Schilder (1967) declared that a tapered root canal allows the compaction of the gutta-percha cone and its close fitting to the canal walls, minimizing the risk of producing extrusion.

At the interface between gutta-percha and canal wall, reaction forces can been distinguished (Fig. 3): normal reaction forces act perpendicular, and shear reaction forces act parallel (friction) to surfaces in contact. When the applied force exceeds the maximum static friction force, surfaces move relative to each other and dynamic friction force occurs. Dynamic friction depends on force squeezing objects together, and on the nature of materials in contact, and has a direction opposite to the motion or the impending motion. However, these frictional phenomena can develop only if the gutta-percha is not too deformable, i.e. in crystalline state. Only if the cone is in crystalline state can the vertical compaction force it to fit more apically

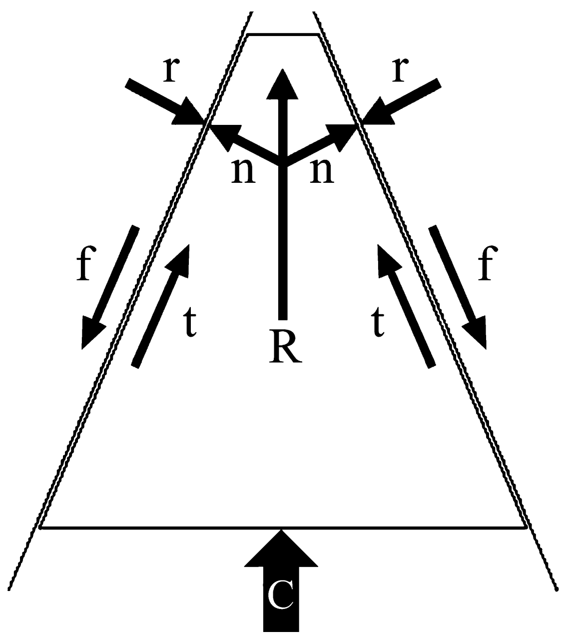

Figure 3 Vectorial decomposition of the compaction force between two inclined planes. C, compaction force that can be decomposed into tangential force (t) and normal force (n). r, reaction force; f, friction force; R, resulting force.

within the smaller and smaller diameters of the tapered main root canal. Thus, a reversible elastic strain may occur, able to increase the force normal to the canal wall, to compress the gutta-percha against the canal walls and squeeze the endodontic cement, and filling the lateral canals. Moreover, an increase of friction also occurs that counteracts the cone motion, and thus its extrusion.

The apical gutta-percha, at the temperatures recorded and advocated by Marlin & Schilder (1973), maintains its more crystalline state and shows low plasticity. If gutta-percha is compacted at those temperatures, only very small elastic and plastic deformation may occur, and the probability that it would flow into irregular spaces is unrealistic. Moreover, these small deformations obviously occur more easily with brands of gutta-percha having lower stiffness, such as the Mynol cones in the present study, and close to the point where the compaction force is applied (Allison *et al.* 1981).

A root canal sealer was not used in this study, as in the study of Smith *et al.* (2000). Only the penetration of the gutta-percha was evaluated at different levels of temperature. The use of a sealer may allow better filling of the root canal system because of its lubricating property. It was not the purpose this study to evaluate the sealer distribution or film thickness. However, a sealer is always indicated with any filling method to reduce microleakage (Skinner & Van Himel 1987, Hata *et al.* 1992).

Conclusions

The three brands of gutta-percha cones, when heated and compacted, showed different capability to flow, and penetrated for more than 0.43 mm into lateral canals having inner diameters of 0.5 mm only at temperatures higher than 47 °C. The rheological significance of these data has to be taken into account in relation to the different canal filling techniques used.

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