Root canal obturation and root integrity

Giuseppe Cantatore describes two obturation techniques that make it possible to treat a higher number of clinical cases successfully at the same time as respecting radicular integrity

The American Association of Endodontists defines root canal obturation as the complete, three-dimensional obturation of the root of canal system, as close as possible to the cemento-dentinal junction without over- or under-filling. Moreover, obturation should be carried out using a minimal amount of biocompatible sealer and the obturated canal should demonstrate a radiographically dense filling extending as close as possible to the cemento-dentinal junction (*AAE Appropriateness of care and quality assurance guidelines*, 1994; Gutmann JL, 1992).

However, this definition overlooks an important requirement in three-dimensional obturation, i.e. the need to maintain the integrity of the root canal walls (Cantatore G, 2000; Cantatore G, 2001; Ruddle CJ, 2002). The clinician should carefully consider the anatomy of the root and the thickness of the residual dentinal walls, in order to choose a minimally invasive canal preparation technique with the least dental tissue loss. This article describes two obturation techniques that make it possible to treat a higher number of clinical cases successfully while respecting radicular integrity. The description is preceded by a short discussion on various issues related to endodontic rationale and an understanding of the current root filling material of choice, gutta percha, which is essential to an appreciation of obturation techniques.

Objectives of cleaning and disinfection

The objectives of cleaning and disinfection of the root canal system prior to obturation are:

• The complete elimination of pulpal tissue and dentin smear layer, especially apically where irrigation is more of a problem (Figures 1 and 2)

• Disinfection of the root canal system and the dentinal tubules.

Irrigating solutions play a significant role in the cleaning and disinfection of the root canal system. A recent study

Giuseppe Cantatore PhD graduated in medicine in 1980 at the University of Rome (La Sapienza). In 1983 he specialized in general dentistry at the same University. Dr Cantatore taught endodontics at the University of L'Aquila from 1987 to 1991 and at Rome (La Sapienza) from 1992 to 1998. Since 2000 he has been an associate professor of endodontics at the University of Verona in Italy. Dr Cantatore is the author of more than 90 articles, most of which are related to the field of endodontics. Dr Cantatore lives and works in Rome, running a clinical practice limited to endodontics

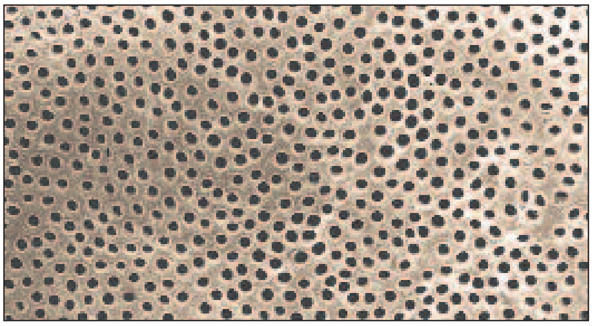


Figure 1: SEM image of the dentinal walls of the apical third after irrigation with 5% sodium hypochlorite solution alternating with 15% EDTA. Note the great number of open dentinal tubules and complete elimination of dentinal mud (SEM 500x)

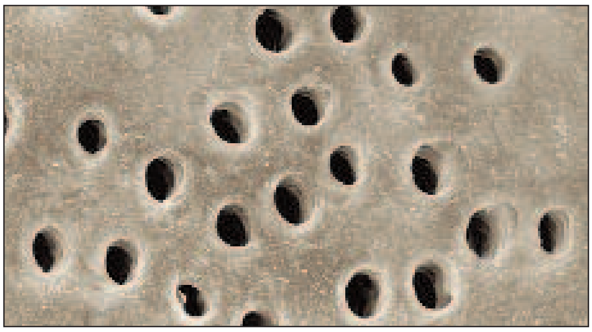


Figure 2: SEM image of the canal walls in the apical region. Note the low number of dentinal tubules and their complete cleaning. No sign of decalcification of tubular openings or of the inter-tubular dentin visible (SEM 200x). Irrigation with 5% sodium hypochlorite sodium, alternating with 15% EDTA

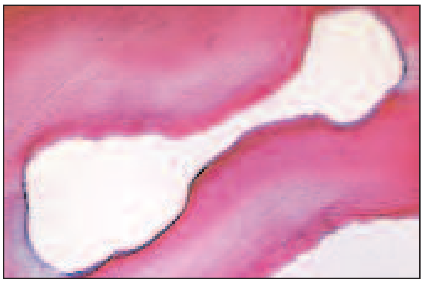


Figure 3: Microscope image of a horizontal section of the apical region of the mesial root of a mandibular molar. Note the significant anastomosis between the two mesial canals not obvious prior to the preparation of the two canals. Complete cleaning of this type of anatomy can only be achieved using the correct irrigating solutions

Figure 4: Thermafil obturation of an upper first molar tooth. Note the conservative preparation in the coronal third, good apical control of obturation materials and the complex anatomy of the mesial root

Figure 5: Preparation objectives are achieved in this second mandibular molar: continuously tapering preparation, respect of the original anatomy, conservative preparation in the coronal third, which facilities action of the irrigation solutions, and three-dimensional obturation with System B

(Calliope D, 2003) shows that the quality of cleaning was directly dependent on the anatomy of canal space. Round and regular canals had cleaner walls, while irregular canals showed a greater quantity of remnants in the coronal, middle and apical thirds. Considering the great frequency of complex canals (Figures 3, 4 and 5), it is recommended that more effort and time should be allocated during the preparation stage to optimize the irrigation, as this is too often neglected.

Mechanical objectives of root canal preparation have been defined as (Buchanan LS, 2002; Gutmann JL, 1992; Ruddle CJ, 2002):
• Continuous tapering preparation
• Maintenance of the original anatomy
• Maintaining the original position of the apical foramen
• Preparation of 'deep shape'
• Maintenance of apical foramen with its original diameter
• Preparation to a predefined taper.

A continuously tapering preparation that is at its widest coronally and narrowest apically creates resistance form, which maintains the gutta percha in the canal space and reduces the possibility of overfilling (Ruddle CJ, 2002). Moreover, the prepared shape of the canal must create sufficient space to optimize the flow of irrigation solution and the compaction of the obturation material (Buchanan LS, 2002). Coronally, however, the canal should be prepared with minimal enlargement to preserve as much tooth structure as possible, which helps to maintain strength and avoid brittleness and the possibility of fracture (Gutmann JL, 1992) (Figure 4). Prior to obturation, knowledge of the exact taper and apical diameter of the prepared canal will facilitate the choice of obturation materials (master cones, compacting instruments, Thermafil obturators) and optimize condensation forces.

Achieving these mechanical objectives is easier now than at any time in the past due to the advent of nickel titanium rotary instruments. Canals can be prepared with minimal numbers of instruments in less time and with minimal risk of complications (Figure 5).

Planning root canal obturation

The question 'when is the best time to obturate the prepared root canal?' is one that has caused much debate within endodontic circles. Many endodontists and clinicians prefer to carry out the entire endodontic procedure in a single visit, even in the presence of an acute periapical abscess, arguing that postoperative pain and the long-term outcome are unaffected by the number of treatment sessions (Gutmann JL, 1992; Mulhern JM, Patterson SS, Newton CW, Ringel AM, 1982; Southard D, Rooney T, 1984). However, other studies have noted that for necrotic teeth with periradicular lesions, a higher success rate is achieved if endodontic treatment is carried out in multiple visits and calcium hydroxide is used as an inter-appointment dressing. The author's view on this issue is as follows – single-visit endodontics should always be carried out except:
• When mechanical objectives and modern irrigation protocols cannot be achieved
• If the canal shows signs of bacterial contamination and if it is not possible to dry it completely (traces of blood or moisture)
• If there are symptoms of acute periapical abscess.

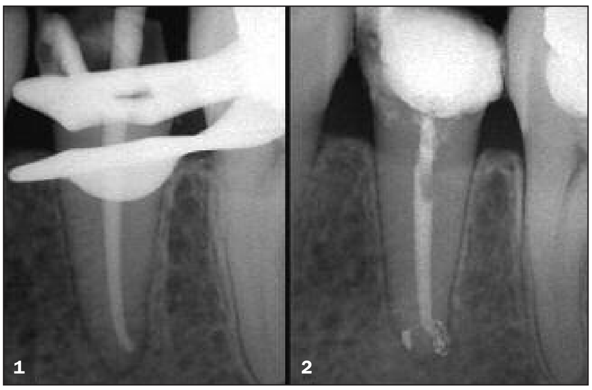


Figure 6: In this second mandibular premolar, the anatomical apex does not correspond to the radiographic apex (1). After System B obturation, two additional exits are noted (2)

Table 1: Ideal conditions for endodontic sealers

1	Adequate consistency and adhesion to the dentinal walls
2	Adequate working time
3	Capacity to produce a hermetic seal
4	Easy handling
5	Radiopacity
6	Expansion at the time of set
7	Disinfectant action
8	Biocompatibility
9	Insolubility in tissue fluids
10	Soluble with solvents used in retreatments
11	Do not discolor dental tissue
12	No antigenic action
13	No mutagenic action

Apical limit of the obturation

The determination of the apical limit of obturation is a controversial issue. The apical constriction, histologicaly located at the cemento-dentinal junction (CDJ), is generally regarded as the ideal position to finish the shaping and cleaning procedure, as well as the optimal position for obturation (Gutmann JL, Witherspoon DE, 2002). Unfortunately, the clinical position of the CDJ compared to the radiographic apex can vary from 0mm to 3mm and is dependent upon various physiological and pathological conditions (Gutmann JL, Witherspoon DE, 2002). Moreover, its radiographic identification is possible only after obturation (Gutmann JL, Witherspoon DE, 2002). The great variation in the position of the CDJ has led to a great divide among endodontists. Some prefer to prepare and obturate within the canal space short of the radiographic apex (Ricucci D, Langeland K, 1998) while others prefer to prepare and then fill to the radiograph apex (Ruddle CJ, 2002). The author's clinical view is based on the following considerations:
• Working short of the radiographic apex can lead to incomplete elimination of pulp tissue. The clinical outcome is unpredictable, since there is no way to assess the state of the remaining pulp tissue. If the tissue is inflamed or infected, the long-term prognosis would be poor
• Clinical experience has indicated that endodontic retreatment is more likely to be required when obturation is incomplete, short and of poor quality (Canatore G, 2001; Nguyen TN, 1991;Torabinejad M et al, 1994). Retreatment of 'long' cases are less frequent and often related to inadequacies in shaping and cleaning procedures
• Determination of working length is now an exact science due to the reliability of modern apex locators (Shabahang S, Goon WWY, Gluskin AH, 1996). Using electronic measurements, radiographically confirmed, one can determine the exact position of the apical foramen and establish the apical limit of preparation and obturation (Figure 6).

Obturation materials

Sealers

An ideal sealer should meet several conditions (Grossman LI, Oliet S, Del Rio C, 1988), as summarized in Table 1. Unfortunately, however, there is currently no perfect endodontic sealer on the market. All have disadvantages that contra-indicate their exclusive use as the sole means of obturation (Gutmann JL, Witherspoon DE, 2002). The following disadvantages should be noted:

- Cellular toxicity
- Poor biocompatibility
- Porosity leading to solubility as a result of apical percolation
- Antigenic action leading to immunologic response
- Low viscosity, which prevents any apical control of the material.

On the other hand, however, the use of minimal quantities of sealer is indicated in all obturation techniques with gutta percha (Gutmann JL, Witherspoon DE, 2002) because of:

- The lubricating action of the sealer supporting the flow of warm gutta percha
- Its ability to compensate for the shrinkage of warm gutta percha (in techniques using warm gutta percha)
- Its ability to compensate for the microleakage of gutta percha in warm gutta percha techniques
- Its ability to penetrate dentinal tubules and therefore enhance the quality of the seal obtained
- The disinfectant effect that neutralizes residual bacteria and prevents delayed contamination.

In conclusion, the choice of endodontic sealer depends on the obturation technique used. With warm gutta percha, cements based on Rickert's original formula (Pulp Canal Sealer) are recommended as they have an extended working time (Block RM et al, 1978). These sealers, when set, have low cellular toxicity and weak inflammatory activity. Moreover, they are easily prepared with ideal viscosity and consistency when in contact with warm gutta percha (Block RM et al, 1978; Cantatore G, 2003).

Gutta percha

Gutta percha is a natural isoprene polymer extracted from the resin and sap of the trees of the Palaquium family, which grow mainly in south-east Asia. Natural gutta percha is very similar to natural rubber: both are complex isoprene polymers, characterized by long carbon chains. The gutta percha exists as a '1-4 trans' configuration, whereas natural rubber exists as a '1-4 cis' isomeric configuration (Cantatore G, Malagnino VA, Giannini P, 1995; Cantatore G, 2003; Marciano J, Michailesco PM, 1989). Pure gutta percha is white, hard and friable and unsuitable as an endodontic material until mixed with other compounds. The gutta percha composition for use in endodontics is as follows (Pommel L, Camps J, 2001):

- Pure polymer of gutta percha: 18.9-21.8%
- Zinc oxide: 59.1-78.3%
- Barium sulphate: 2.5-17.3%
- Waxes: 1- 4.1%
- Colorants and antioxidants: 3%.

The natural polymer is subjected to several thermal cycles so that it can be correctly mixed with the other components. At the end of the cycling process, the gutta percha, from a chemical point of view, consists of a complex but disordered configuration of polymer chains.

The isomeric stereo configuration, identified by Bunn (1942) is ß phase of gutta percha and is the main component of gutta percha cones. The ß phase, however, is not the only isomeric stereo configuration of gutta percha. In the natural polymer, before heat treatment, the polymer chains are regularly arranged in the α phase. α phase gutta percha is hard and friable in its solid state and its viscosity decreases after thermoplasticization (Bunn CW, 1942; Cantatore G, Malagnino VA, Giannini P, 1995; Marciano J, Michailesco PM, 1989). The two crystalline phases of the gutta percha are interchangeable dependent on the temperature of the material (Marciano J, Michailesco PM, 1989; Schilder H, Goodman A, Aldrich W, 1974):

- Between 42°C and 48°C, the ß phase changes into α phase
- Between 53°C and 59°C α changes into an amorphous phase
- At roughly 80°C, the polymer melts completely
- During cooling, the gutta percha crystallizes again into phase ß and during this process significant contraction occurs.

As a result, the reheating temperature of gutta percha is a critical factor during obturation procedures. The higher the heating temperature, the more significant the contraction during cooling and the more important the necessity to compensate for this by lateral and vertical compaction (Figure 7).

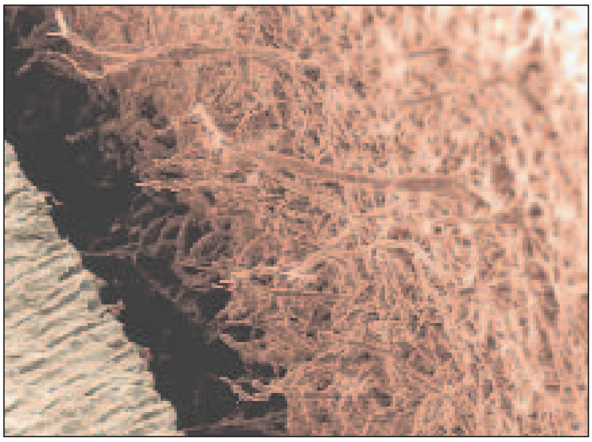


Figure 7: SEM image of the interface dentin/gutta percha of a canal obturated with low viscosity gutta percha without sealer and/or compaction after cooling. The irregularities of gutta percha adjacent to the dentinal tubules is marked. A significant empty space appears between the dentin and the gutta percha after contraction of the gutta percha (SEM 500x)

Gutta percha, as used in endodontics, is produced in the form of cones, either standardized or non-standardized. Standardized cones are sized according to ISO standards for root canal files with taper 2% for diameters from 15 to 140. Non-standardized cones are more tapered and are described as extra-fine, fine-fine, medium-fine, fine, fine-medium, medium, medium-large, large and extra-large. Exact taper and diameter of the point of non-standardized cones are not specified. The same size cones produced by different manufacturers can vary significantly. To facilitate the choice of master cone and to match it with the shape of the prepared canal, a new generation of non-standardized cones has been introduced. These cones are characterized by a standardized core diameter (usually 0.20mm) and are available in five different tapers (from 4% to 12%). Therefore the choice of a perfectly fitting gutta percha master cone corresponds to the same taper of the last instrument used to complete instrumentation. Simply cut the end off to correspond to the same diameter as the apical foramen with a gauge. Gutta percha for use in endodontics is also available in the form of small pellets, cannules (Obtura, Ultrafil), re-heated syringes (MicroSeal) and obturators, including a solid plastic carrier (Thermafil).

All of these types of gutta percha must be preheated in suitable devices before use (except Obtura) and can be

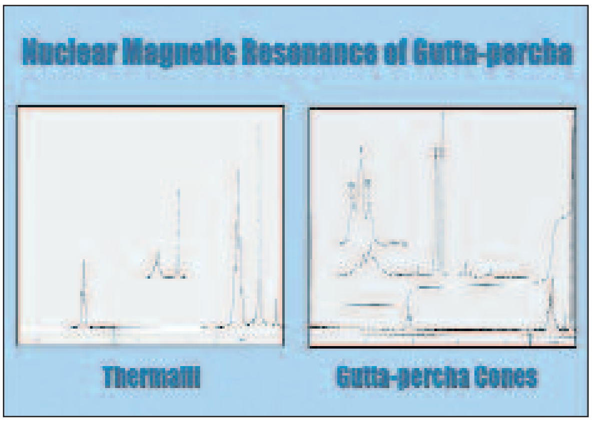


Figure 8: Spectral analysis of two types of gutta percha: Thermafil and conventional cones. The position of the peaks indicates that the gutta perchas are chemically identical

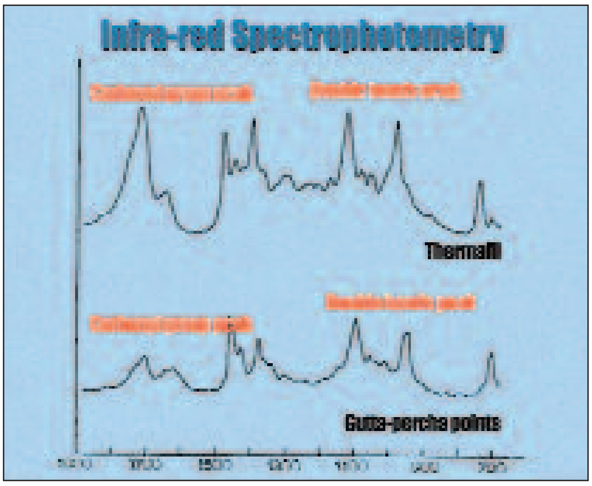


Figure 9: Infrared spectro-photometry of two types of gutta percha: conventional Thermafil and cones. The position and the extension of the peaks indicate the presence of alpha and beta phases and amorphous for the two types of gutta percha

defined according to their physical properties. Thermafil, Ultrafil and MicroSeal, however, are not true α phase gutta percha for the following reasons:

- They can be heated several times with the same properties but the true α phase is very unstable (Cantatore G, Malagnino VA, Giannini P, 1995; Malagnino VA, Cantatore G, Lupol I, 1994)
- Their melting point is 10°C lower than that of gutta percha in ß phase (Malagnino VA, Cantatore G, Lupol I, 1994)
- Magnetic nuclear resonance demonstrates that their spectral peaks are identical to those of ß phase (Cantatore G, Malagnino VA, Giannini P, 1995) (Figure 8)
- Under infrared spectro-photometry (Camerucci D, 2003), α phase gutta percha shows three principal peaks: the first is in a range between 844 cm^{-1} and 862 cm^{-1} and corresponds to α phase; the second is in the range between 848 cm^{-1} and 750 cm^{-1} and corresponds to ß phase; the third is 840 cm^{-1} and corresponds to the amorphous phase.

Thermafil, MicroSeal and Ultrafil therefore cannot be regarded as α phase gutta percha as the hybrid compound is characterized by the presence of the three crystalline phases: α, ß and amorphous (Camerucci, 2003) (Figure 9).

- Infrared spectral analysis indicating the presence α, ß and amorphous phases (Camerucci D, 2003) are the components of AutoFit and Maillefer gutta percha (Figure 9). Even though all gutta percha cones with their α phase components are identical, their clinical behavior is completely different. When they are thermoplasticized, they become very sticky and fluid with low viscosity, excellent flow and the capacity to penetrate deeply into dentinal tubules, which increases the quality of the seal obtained (Camerucci D, 2003; Cantatore G, Malagnino VA, Giannini P, 1995) (Figure 10).

Optimization of obturation techniques with thermoplasticized gutta percha

The flow of semi-solid materials, such as gutta percha and sealers, follows the law of Hagen-Poiseuille and depends on the condensation forces, the viscosity of gutta percha and the sealer, as well as the curvature and length of the canal (Figure 11).

Condensation forces produced during the compaction of hot gutta percha are divided into two components (Saw LH, Messer HH, 1995; Telli C, Gulkan P, Gunel H, 1994):

- Lateral forces, which tend to push the filling material against the canal walls and into lateral canals
- Vertical forces, which tend to push filling materials in an apical direction increasing the risk of extrusion.

Optimization of condensation forces depends therefore on a delicate balance between the taper and the diameter of the canal, master cone and pluggers used for condensation. A continuously tapered root canal preparation will mitigate the effect of vertical forces and prevent apical extrusion of gutta percha and sealer. A tapered master cone, matched perfectly with the same shaped canal, will increase lateral pressure during condensation. The use of pluggers of similar taper and diameter to the master cone will allow direct pressure on the gutta percha and avoid dangerous pressure against the canal wall (Saw LH, Messer HH, 1995; Telli C, Gulkan P, Gunel H, 1994).

Low viscosity gutta percha flows easily into the intricacies of the root canal system and requires condensation forces lower than those of gutta percha with high viscosity. Low viscosity gutta percha as used in the Thermafil technique explains the effectiveness of this technique in the obturation of lateral canals (Goldberg F, Artaza LP, De Silvio A, 2001) and internal resorptive defects

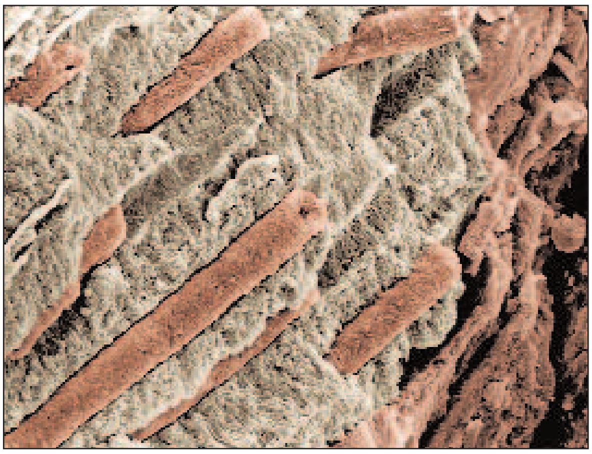


Figure 10: Penetration of Thermafil gutta percha, used without sealer inside the dentinal tubules (SEM 200x)

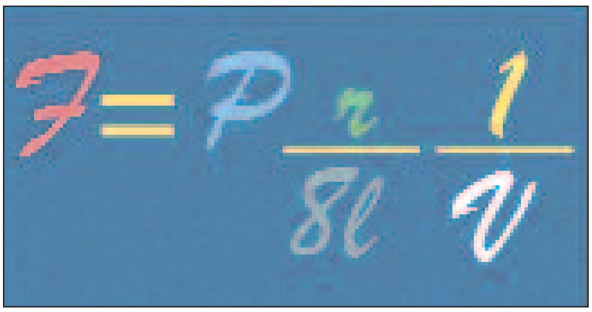


Figure 11: Law of Hagen-Poiseuille, which governs the flow of high viscosity polymers. In root canal canal obturation, the flow of the thermoplasticized gutta percha and of sealer (F) will depend on: the condensation forces (P), the canal radius (r), the length of the root (l) and the viscosity of the polymer (v)

(Goldberg F, Massone EJ, Esmoris M, Alfie D, 2000), despite the weak forces developed during condensation (Figure 12).

Abrupt reduction of the radius of the canal reduces the flow of gutta percha and sealer, while continuous taper with progressive reduction of the radius obtained with rotary nickel titanium instruments can minimize this problem. In long canals, the flow is reduced gradually toward the apex. To optimise the flow therefore there are three possibilities:

- Increase the radius of the canal
- Choose gutta percha with low viscosity
- Increase the condensation forces.

System B

The System B obturation technique, developed by LS Buchanan (1994, 1996) in 1987, should be regarded as a simplification of the original vertical compaction of hot gutta percha technique of Dr Schilder, with the same outcome.

• The System B heat source

This is an electronic device connected to a rechargeable battery (Figure 13). On the front of the device there are two switches (start and heating mode), two buttons (to choose temperature and heating power) and a hand control plug. The parameters used for the System B heat source are normally: maximum output, temperature of approximately 200°C and use mode on 'touch'. A flexible cable is connected to the heat source, which carries at its end an activation ring and an insertion system for the pluggers. A microprocessor within the unit adjusts the temperature, maintaining it constantly at the tip of the plugger throughout the heating phase (Machtou P, Amor J, Lumley P, 1998).

• System B pluggers

Buchanan pluggers (Figure 14) are designed to fill by heating, plugging, softening and compacting gutta percha during a continuous wave of condensation. System B pluggers are available in four sizes (fine, fine-medium, medium and medium-large) with the same tip diameter of 0.50mm but with increasing tapers from 6% to 12 %. The pluggers are constructed with a double metal layer and an internal electric wire. This allows the pluggers to heat from their end, but at the same time reduces their flexibility.

• Buchanan manual pluggers

Manual pluggers are available in two sizes with two ends, one conical made of nickel titanium and the other of stainless steel. Buchanan pluggers can be used during the coronal to apical downpack in order to increase the compaction pressure on the apical gutta percha and/or during back filling. Due to the flexibility of the conical nickel titanium end, the manual pluggers can be used effectively even in very curved canals.

• Gutta percha cones

Optimization of condensation forces in the System B technique necessitates good matching of the gutta percha cones with the shape and taper of the canal. Autofit are available in four conicities: fine (6%) fine-medium (8%), medium (10%) and large-medium (12%). All these cones must be cut with a gauge to obtain a tip diameter corresponding to the apical diameter at the most apical extent of the preparation. Analytic Technology also markets back filling gutta percha cones identical to the Autofit cones but cut to approximately 0.5mm at their end, which facilitates back filling procedures.

• Obtura II

Obtura II is a device for delivering hot gutta percha and is ideal in the back filling phase. The gutta percha, for the Obtura gun, is available in sticks of two different viscosities, which are inserted into the heated injection system softened at approximately 180-200°C and injected with flexible needles (20 and 23 gauge) (Figure 15).

Obturation sequence (Figures 16 and 17)

• Choice of the pluggers

Choose a System B plugger that binds 4mm from working length and place a rubber stop. Choose two manual

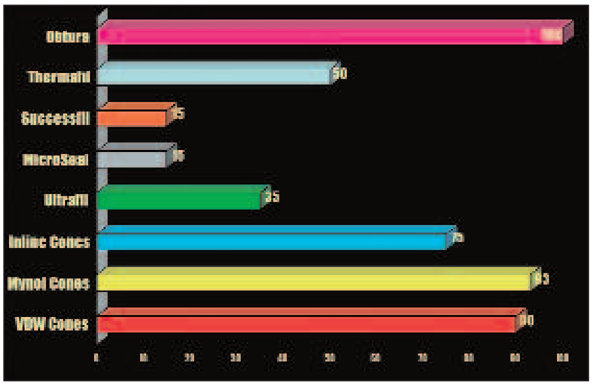


Figure 12: Viscosity of several brands of gutta percha after thermoplasticization

Figure 13: System B heat source

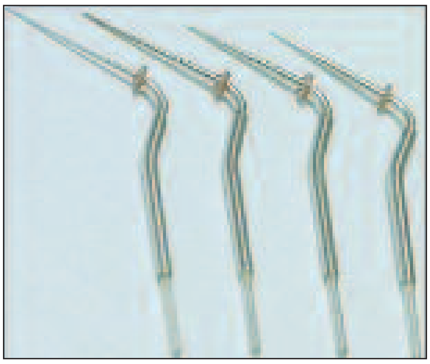
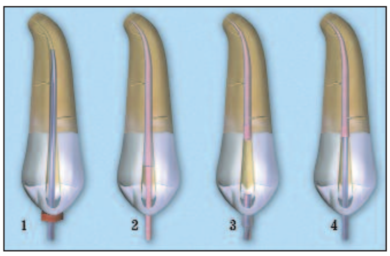
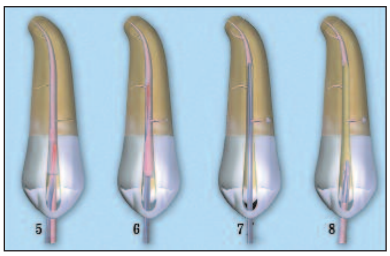


Figure 14: Buchanan pluggers are available in four sizes

Figure 15: Obtura II system, ideal for backfilling the canal after the System B downpack





Figures 16 and 17: Downpack wave of condensation carried out with System B. Selection of the plugger (1), fitting of cone (2), sectioning of the master-cone (3) and condensation of the master-cone at the canal entrance with a manual plugger (4). Progressive penetration with System B plugger activated in the canal up to 4mm from the binding point (5, 6), passive movement to the binding point (7), removal of the plugger (8). (Reprinted with kind permission of LS Buchanan.)

pluggers, one in nickel titanium that binds 4mm from working length and the stainless steel plugger, which binds in the middle third of the canal.

• Fitting of the cone

Choose a gutta percha master cone of identical taper to that of the prepared canal, cut its end to the same size as the apical diameter, insert the cone inside the canal and take an X-ray. If the X-ray confirms that the cone is correctly fitted, it can be sealed to the length with a small amount of Rickert formula sealer.

• Coronal-apical compaction (the down pack)

Sever the master cone at the entrance of the canal using a heated System B plugger and condense it with the stainless steel hand plugger. Place the end of the System B plugger at the canal opening, activate it with the touch-spring and drive it through the gutta percha in one movement, without interruption, to within 2mm of its binding point. Release the spring while maintaining

Figure 18: Extracted tooth, after obturation with the System B technique. Note the complexity of the root canal system

Figure 19: Mandibular molar with complex canal anatomy showing the capacity of the System B technique to obturate three-dimensionally

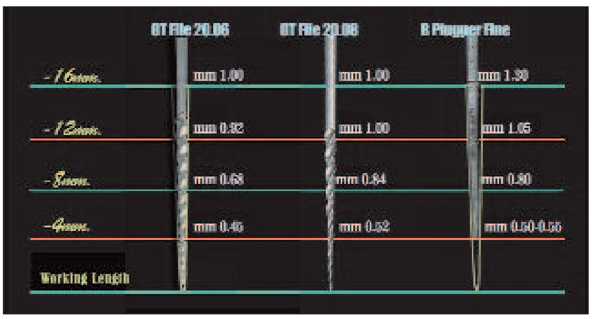


Figure 20: Required diameters for correct use of fine and medium-fine System B pluggers, corresponding to GT files 20.06 and 20.08 respectively

apical pressure, moving to the binding point (if necessary, give one second of additional heat). Maintain the apical pressure for five seconds to prevent the accidental removal of the entire cone of gutta percha, activate the spring for one second and withdraw it from the canal with the coronal mass of gutta percha. Finally, use the nickel titanium end of the Buchanan manual plugger and firmly condense the gutta percha before it completely solidifies (Buchanan LS, 1996; Cantatore G, 2000; Cantatore G, 2001; Machtou P, Amor J, Lumley P, 1998).

• Coronal fill (the back fill)

After the down pack, part of the canal remains empty. The depth of this can vary according to the mass of gutta percha eliminated by the System B plugger, but it generally corresponds to the length of the canal less 4-5mm. This space can be immediately used to place a post but if not, it must be filled. The simplest way to fill this space is to use the Obtura system.

Preheat the apparatus to roughly 200°C, insert a stick of gutta percha, pre-curve the needle and place it until it touches the apical mass of gutta percha (Cantatore G, 2000). Activate the Obtura and release gutta percha while allowing the increasing mass to push the needle out of the canal. When the canal space is completely filled, condense the gutta percha at the canal entrance using the end of a stainless steel manual System B plugger and take an X-ray to confirm the result. As an alternative to the Obtura system, one can use back fill gutta percha cones by heating them and condensing them with a System B plugger (Buchanan LS, 1996; Cantatore G, 2000; Cantatroe G, 2001; Machtou P, Amor J, Lumley P, 1998).

To optimise the System B technique, it is necessary (Cantatore G, 2001):

• To choose a System B plugger that closely approximates the shape of the canal
• To adapt a master-cone perfectly to the prepared canal space
• To pre-curve the plugger and to check its insertion to the binding point
• To use sealer with an extended working time
• To use a radiograph to check the depth and condensation of the mass of filling
• To compact up to 4mm to the working length
• To use the manual pluggers after down pack and back fill in order to obtain a more compact obturation
• When the Obtura needle is completely inserted, wait two or three seconds before injecting gutta percha, which softens the apical gutta percha and creates a homogenous mass
• If the X-ray indicates the presence of voids, repeat the procedure.

Advantages of the System B technique (Cantatore G, 2001, Machtou P, Amor J, Lumley P, 1998) are:

• Three-dimensional obturation that can fill complex anatomy as a result of high condensation forces (Figures 18 and 19)
• Predictable results
• Excellent apical control of obturation materials
• Immediate preparation of post space.

Disadvantages of the System B techniques

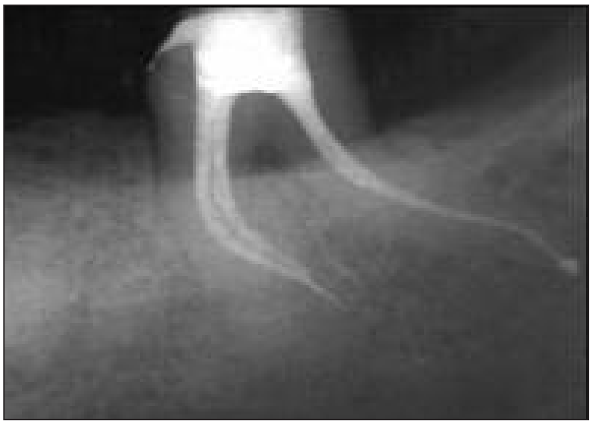
• The need for preset canal diameters. The diameter of the System B plugger at its end is 0.50mm. Since the plugger must be introduced up to 4mm from working length, the minimal diameter of the prepared canal diameter at this level must be approximately 0.55mm (Figure 20).

Achieving this diameter can be difficult in long, calcified or curved canals. In the coronal third, the minimal diameter for the introduction of the 'fine' B pluggers varies according to the length of canal. In a 10mm canal, the minimum diameter is roughly 0.90mm while in a long canal of 16mm, the minimum diameter is approximately 1.30mm (Figure 20). Consequently, in long and thin roots, making space to allow the use of the B plugger, even the finest, can weaken the canal wall in the coronal third

• Additional enlargement of the preparation of very curved canals is necessary to allow the insertion of the B pluggers, since their flexibility is limited, especially in the biggest sizes (Figures 21 and 22)

• The System B back fill technique without the Obtura system is difficult and inconsistent

• Unpredictable results for teeth with open apexes and severe external resorptions.



Figures 21 and 22: Insertion of System B pluggers to the required depth in very curved canals may necessitate considerable over-widening of the coronal portion of the canal and thus weakening of this area of the root. In this mandibular molar, the canals were prepared to GT file size 30.06 (mesial) and 30.08 (distal) (Figure 21), which in this instance allowed satisfactory obturation with System B (Figure 22)

Thermafil

The Thermafil obturation technique, developed by Dr WB Johnson in 1978, is a carrier-based system. Preheated gutta percha is introduced and condensed into the root canal system with a plastic carrier of predefined diameter and taper. The principal characteristic of the Thermafil system is therefore the presence of a carrier within the body of obturation material. This does not seem, however, to affect the sealing capacity of this technique, as has been shown in many studies (Haikel Y et al, 2000; Hata G et al, 1995; Pommel L, Camps J, 2001a; Pommel L, Camps J, 2001b). This research clearly demonstrates the three-dimensional obturation obtained with Thermafil and provides as hermetic a seal as vertical condensation and System B techniques (Pommel L, Camps J, 2001a; Pommel L, Camps J, 2001b) and is certainly superior to that obtained by lateral condensation (Dummer PM et al, 1984; Haikel Y et al, 2000) (Figure 23).

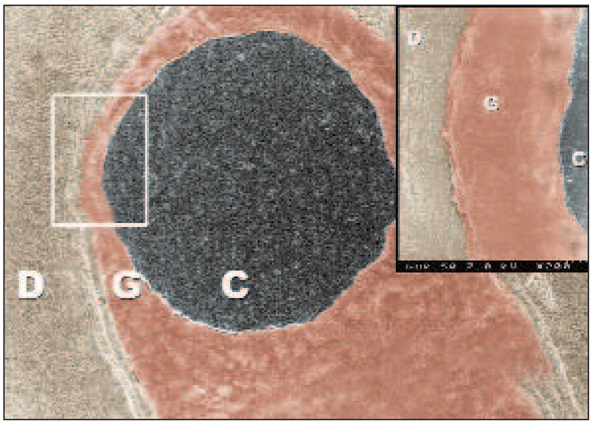


Figure 23: Two SEM images of a horizontal section (using a resin model) of Thermafil obturation. (D = dentin, G = gutta percha, C = carrier.) Note the good adaptation of Thermafil gutta percha to the dentin and the carrier and, in particular, on the left of the image, the quality of seal without apparent voids (SEM 70x and 200x)

Thermafil obturators

Thermafil obturators comprise a flexible plastic carrier covered on approximately 16mm of its length with a layer of gutta percha. The gutta percha extends approximately 1mm from the tip of the carrier. Thermafil obturators correspond to ISO standards from size 20 to size 140 at the apical end of the carrier. The carrier has a 5% taper, a longitudinal groove to facilitate retreatment and five rings placed at 18mm, 19mm, 20mm, 22mm and 24mm from the end in order to facilitate correct insertion length. Thermafil gutta percha is hard and friable in its solid state, but when softened becomes thermoplastic with excellent proprieties of flow and low viscosity. Thermafil gutta percha has excellent sealing capacity (Dummer PM et al, 1994; Haikel Y et al, 2000; Pommel L, Camps J, 2001a; Pommel L, Camps J, 2001b) and can penetrate lateral canals and dentinal tubules, increasing the quality of the seal (Cantatore G, Malagnino VA, Giannini P, 1994; Goldberg F, Artaza LP, De Silvio A, 2001; Goldberg F et al, 2000; Leonard JE, Gutmann JL; Guo IY, 1996) (Figure 24). In spite of its recognised sealing qualities, however, Thermafil, like all types of gutta percha, tends to contract on cooling. To compensate for this, sealer is always recommended (Hata G et al, 1995).

GT obturators

GT obturators were developed by Dr Buchanan (1996). As an alternative to the existing Thermafil line they offer the user an option other than the System B technique, while providing a perfect match for the GT file system. While identical to Thermafil, GT obturators are available in the taper and diameter that correspond exactly to GT rotary files. Therefore, there is a GT obturator for each GT file and their three principal series with apical diameters of 0.20mm, 0.30mm and 0.40mm and four tapers (4%, 6%, 8% and 10%). There is an additional series of three 12% taper obturators and apical diameters of 0.50mm, 0.70mm and 0.90 mm.

GT 4% taper obturators require a canal prepared with a 4% tapered instrument, which allows the clinician the possibility of preparing a more conservative root canal

Figure 24: Extracted tooth with canals prepared with ProTapers and sealed with four Thermafil obturators. Note the significant number of lateral canals

preparation that can be useful in the case of long and thin roots (Figure 25).

The Thermaprep oven

The Thermprep oven heats up the obturators and can be used for both Thermafil and GT obturators. Two obturators can be heated simultaneously with three different warm up times depending on the size of the carrier.

Verifiers

Verifiers are nickel titanium instruments that are used to check the diameter of the canal corresponding to the correct size of Thermafil carrier. Since the verifiers have radial lands, they can be used in minor adjustment to the shaped canal. Verifiers are not available in the GT obturator system because the choice of the obturator is made according to the last GT file used to length, which in itself is a verifier.

Thermacut bur

Thermacut is a steel bur used at high speed, available in four different diameters and 25mm long. The burs are used without water spray to separate the carrier at the canal entrance. The bur's action is based on friction and heat rather than a cutting action. The carrier can also be separated with a System B plugger by increasing the temperature to approximately 300°C.

Post Space drills

Post Space drills are high-speed steel burs, available in two diameters with the same length of 25mm. They do not have any cutting capacity. Their action is based on friction and heat, high enough to plasticize and sever the plastic carrier. Two parallel axial grooves facilitate removal of the carrier. The use of the Post Space drill is very simple: identify the plastic carrier, touch the plastic with the drill and at maximum speed without water spray insert the drill to the desired depth to eliminate the carrier and gutta percha. The coronal portion of the canal will, of course, require additional preparation for post space using conventional burs.

Oturation sequence (Figures 26 and 27)

• Choice of the obturator

The final outcome of Thermafil obturation depends mainly on the choice of the obturator. The perfect obturator is a carrier with an apical size that corresponds to the apical diameter of the foramen with a taper slightly less than that of the preparation. This discrepancy is necessary to optimize the flow of gutta percha and sealer.

• Placement of sealer

Place a little sealer on the end of a paper point and place it inside the canal from top to bottom to create a thin layer all along the canal walls. If necessary, take a second point to dry and eliminate excess sealer. Sealer is indicated in all cases of Thermafil obturation to lubricate the canal walls and compensate for the contraction of gutta percha (Lee CQ et al, 1998). Kerr RCS sealer with extended working time maintains viscosity in contact with hot gutta percha. Resin sealer, however, such as Top Seal or AH plus+ tends to become too fluid and difficult to control in contact with the hot obturator.

• Insertion of the obturator

Take the selected obturator and, using a scalpel, cut back the gutta percha to expose the end of the carrier. Eliminating gutta percha from this region reduces the possibility of overextending the gutta percha. Place the rubber stop on the shaft of the obturator so that ir can be placed at 0.5-1mm from the working length and heat it in the ThermaPrep oven. Check that the gutta percha is correctly plasticized and slowly insert the obturator to its final position, working length minus 0.5-1mm.

• Sectioning of the obturator

After insertion of the obturator, wait 5-10 seconds until the gutta percha starts to cool and cut the obturator at the canal entrance using the Thermacut bur or the System B plugger.

• Final condensation

Condense the gutta percha using a manual plugger at the entrance of the canal. In oval shaped canals additional gutta percha cones can be placed inside the hot Thermafil gutta percha, before separating the carrier.

Optimization of the Thermafil obturation technique

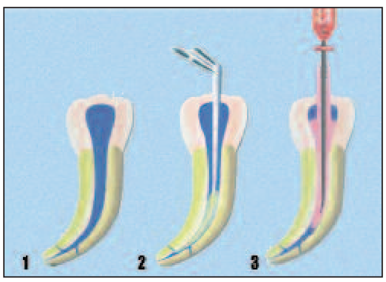
To optimize the Thermafil technique, one must (Cantatore G, 2001):

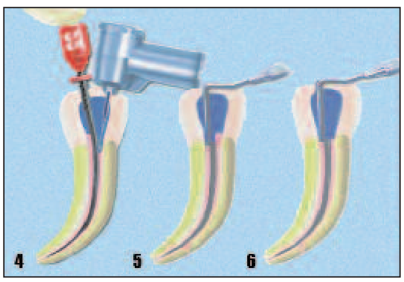
• Prepare the canal to a preset diameter and taper
• Choose the adequate obturator
• Reduce the quantity of sealer to a minimum
• Remove surplus gutta percha at the end of the cold obturator
• Place the rubber stop 1mm from the working length
• Check the plasticity of the heated gutta percha
• Insert the obturator very slowly
• Cut off the carrier by firmly holding it with the left hand (if right-handed)
• Take an X-ray before separating the obturators. In the event of an error, it will be easy to remove and start the obturation sequence again (Figures 28 and 29).

Advantages of Thermafil obturation techniques

• Three-dimensional obturation (Figures 30 to 33)
• Minimal taper and diameter of the prepared canal is required. The traditional Thermafil obturator requires ideal taper of the canal between 5% and 6% with a minimum

Figure 25: Endodontic treatment of a mandibular molar with roots of 33mm (1). By using GT obturators 0.04 for the obturation (2), over-widening of the canal was limited to 0.04 taper, maintaining the integrity of the hard tissue, particularly in the apical third





Figures 26 and 27: Sequence of Thermafil obturation: prepare the canal according to a predefined diameter and taper, choose the corresponding GT obturator or Thermafil (1), place a small quantity of sealer using a paper point (2), slowly introduce the preheated Thermafil (3), cut off the handle at the canal entrance with the Thermacut drill (4), condense the gutta percha at the entrance with a hand plugger (5, 6) apical diameter of 0.20mm. If GT obturators are used, minimal taper of 4 % and an apical diameter of 0.20mm is possible. In general, canals prepared for Thermafil can be prepared more conservatively than those prepared for the System B technique. This is particularly useful in long, fine and curved roots (Figure 34) and:

- Is ideal for use in curved and long canals (Figure 35)
- Where there are intracanal obstructions, the high flow of Thermafill gutta percha enables the filling material to bypass these obstructions (Figure 36).

Disadvantages of Thermafil obturation techniques

- Risk of extrusion of gutta percha
- Preparation of post space and retreatment require more time than System B
- Difficult to use in canals with bi- or tri-furcation or in teeth with multiple canals with canal openings in close proximity to each other, especially in a small pulp chamber (Figure 37) or in the presence of open apices and severe external resorptions.

Retreatment of Thermafill sealed canals

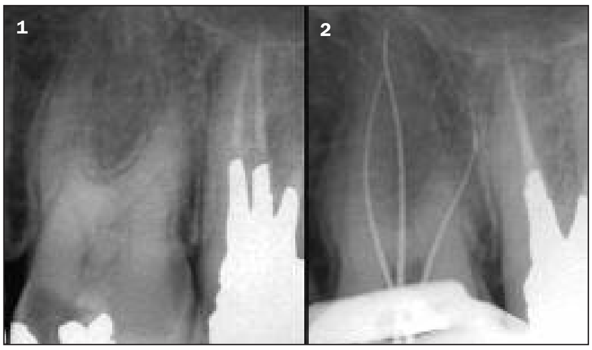
System B pluggers are the ideal solution for the retreatment of Thermafil-filled root canals. Using a fine or medium-fine System B plugger and increasing the heating temperature to 300-350°C, isolate the plastic carrier, touch the plastic with the end of the plugger, activate the plugger and penetrate the canal by thermoplasticizing the carrier up to 3-4mm. Remove the plugger immediately and firmly screw a Hedstroem file of 25 or 30 diameter into the softened plastic until it cools and adheres to the file. Remove the Hedstroem file, with the carrier attached, in one movement. This technique is safe, quick and the time of the operation is generally no more than six to seven minutes (Wolcott JF, Himel VT, Hicks ML, 1999).

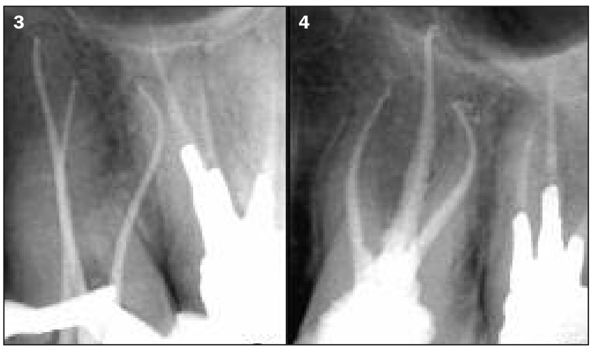
Ultrasonic technique

This retreatment technique is identical to that described in the preceding section, with the exception that softening the plastic carrier is carried out using an ultrasonic tip. The best tip for this is the Pro Ultra no. 3 or 4 or a BUC no. 1.

Rotary instruments

Remove part of the gutta percha using a solvent, which isolates the plastic carrier. Take a Profile 25.06 or a ProTaper F2, rotate at 150 rpm and penetrate the gutta percha between the plastic carrier and the canal wall, progressing deeper and deeper into the canal. Penetration is facilitated by the longitudinal groove located on the axis of the carrier. Continue file rotation until the carrier is isolated and removed from the canal. This technique is safe and quick in straight canals but can lead to canal transportation in curved roots.





Figures 28 and 29: Obturation with the Thermafil method requires four radiographic images: diagnosis (1), working length (2), check before obturation (3) and final result (4)

Clinical case illustrating the capacity of the Thermafil technique to produce three-dimensional obturation even in curved channels.

Figure 30: A preoperative radiograph of a mandibular molar suggesting significant dental tissue loss and an extensive periapical lesion in this mesial root

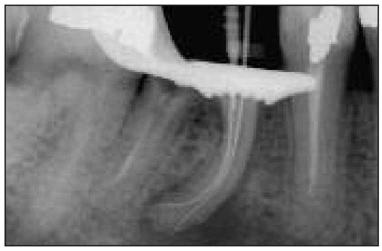


Figure 31: Radiograph to determine the working length of the mesial canals showing marked curvature

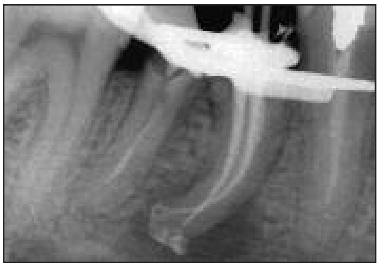


Figure 32: Postoperative radiograph after obturation of the mesial root, showing communication between the two mesial canals

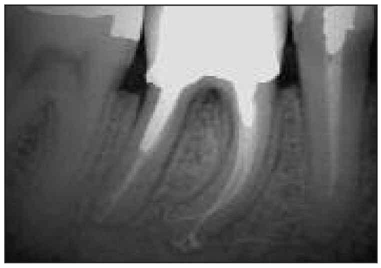


Figure 33: One-year radiograph showing healing of the periapical lesion

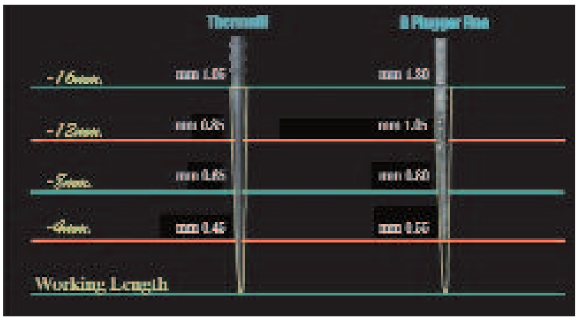


Figure 34: Comparison of the canal diameters required to use a Thermafil 25 or fine System B plugger correctly. The difference between the diameters increases with the length of the root. Thus, preparation for Thermafil can be considered as more conservative than for System B

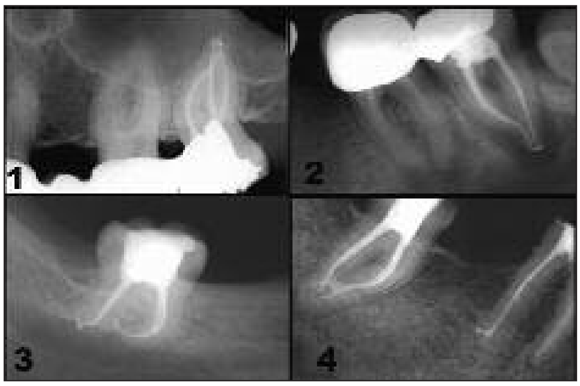


Figure 35: Four clinical cases show how the Thermafil technique perfectly seals very curved canals in a 27 (1), a 37 (2) and two mandibular molars

System B or Thermafil?
System B is indicated for:
• Roots with thick walls and canals up to 21-22mm
• Distal canals of mandibular molars
• Palatal canals of molars
• Canals with bi/tri-furcation
• Moderate apical resorption
• Premolars with complex anatomy.
Thermafil is indicated for:
• Thin roots
• Mesial canals of mandibular molars
• Buccal canals of the maxillary molars
• Intracanal obstructions
• Long, severely curved and calcified canals
• Premolars with separate canals.

Conclusion

The essential elements of this article can be summarized as follows:
• Root canal preparation, cleaning and obturation are closely dependent
• The root canal should be prepared to a predefined taper and diameter to facilitate the choice of gutta percha cones, pluggers and obturators to optimise condensation forces
• A continuous tapered preparation provides resistance form and respects radicular integrity, maintaining root strength
• Obturation techniques using hot gutta percha offer more versatility and better results than the 'cold' techniques
• Using two complementary obturation techniques like Thermafil and System B, both based on the compaction of gutta percha softened by heat, it is possible to manage most clinical situations successfully
• Neither technique alone can manage every clinical situation
• In long and curved canals, the taper and diameter required for the correct introduction of Buchanan pluggers can lead to structural weakening of the root, which can have an effect on outcome. A classic example is the mesial root of the mandibular molar, which frequently demonstrates a distal concavity, reducing the distal thickness of the root. In such fragile roots, reducing the taper of the preparation, which is possible when Thermafil obturation is considered, will minimize tissue loss and preserve the integrity of the tooth over time.

Figures 36: In this clinical case, the high fluidity of Thermafil gutta percha successfully sealed a canal with a prior separated instrument in a canal after having bypassed the broken fragment with a manual steel file (1,2)

Figures 37: In cases of premolars with three canals, the use of Thermafil can be difficult because of restricted space and proximity of canal openings. In these cases of multiple canals with limited pulpal access the System B technique is indicated

References

American Association of Endodontists (1994) *Appropriateness of care and quality assurance guidelines*. AAE, Chicago

Block RM, Lewis RD, Sheats JB, Burke SH (1978) Cell-mediate immune response to dog pulp tissue altered by Kerr Rickert's sealer via the root canal. *Oral Surg Oral Med Oral Pathol*. **46(4)**: 567-575

Buchanan LS (1994) Vertical condensation of warm gutta percha: observations regarding a classic technique. *Dent Today* September: 1-7

Buchanan LS (1996) The continuous wave of obturation; 'centered' condensation of warm gutta percha in 12 seconds. *Dent Today* January: 1-9

Buchanan LS (2002) Innovation in endodontic instruments and techniques: how they simplify treatment. *Dent Today* **21(12)**: 52-61

Bunn CW (1942) Molecular structure and rubberlike elasticity, part I: The crystal structure of ß gutta percha, rubber and polychlorafene. *Proc R Soc*. **A180**: 40

Calliope D (2003) *Analisi comparativa al microscopio ottico di 3 metodiche di irrigazione canalare*. Master Thesis, University of Verona

Camerucci D (2003) *Dental gutta percha, characteristics of four different brands: GT cones, Microseal, Maillefer cones and Thermafil*. Master Thesis, University of Rome La Sapienza.

Cantatore G, Malagnino VA, Lupoli G (1994) Resonance Magnetique Nucleaire (1H-RMN and 13C-RMN) des differents branches de gutta percha. *Rev Fr Endod* **2**: 65-68

Cantatore G, Malagnino VA, Giannini P (1995) Guttaperca Thermafil: analisi delle capacità sigillanti. *Dent Cadmos*. **11**: 38-47

Cantatore G (2002) Evoluzione delle tecniche di otturazione canalare: le tecniche classiche. *Dent Cadmos*. **3**: 11-27

Cantatore G (2001) Thermafil versus System B. *Endod Prac*. **4(5)**: 30-39

Dummer PM, Lyle L, Rawle J, Kennedy JK (1994) A laboratory study of root fillings in teeth obturated by lateral condensation of gutta percha or Thermafil obturators. *Int Endod J*. **27(1)**: 32-38

Goldberg F, Artaza LP and De Silvio A (2001) Effectiveness of different obturation techniques in the filling of simulated lateral canals. *J Endod*. **27(5)**: 362-364

Goldberg F et al (2000) Comparison of different techniques for obturating experimental internal resorptive cavities. *Endod Dent Trauma* **16(3)**: 116-121

Grossman LI, Oliet S, Del Rio C (1988) *Endodontics*. 11th edition, Philadelphia, Lea & Febiger

Gutmann JL (1992) The dentin root complex: anatomic and biologic consideration in restoring endodontically-treated teeth. *J Prosthet Dent*. **67**: 458-467

Gutmann JL, Witherspoon DE (2002) Obturation of the cleaned and shaped root canal system. In: *Pathways of the pulp*. 8th edition, Mosby, 293-364

Haikel Y, Freymann M, Fanti V, Claisse A, Poumier F, Watson M (2000) Apical microleakage of radiolabeled lysozyme over time in three techniques of root canal obturation. *J Endod.* **26(3)**: 148-152

Hata G, Kawazoe S, Toda T, Weine FS (1995) Sealing ability of thermoplasticized gutta percha fill techniques as assessed by a new mandhod of determining apical leakage. *J Endod.* **21(4)**: 167-172

Johnson WB (1978) A new gutta percha technique. *J Endod.* **4**: 184-188

Lee CQ, Cobb CM, Robinson SJ, Lamartina T, Vo T (1998) In vitro evaluation of the Thermafil technique with and without gutta percha coating. *Gen Dent.* **46(4)**: 378-381

Leonard JE, Gutmann JL (1996) Apical and coronal seal of roots obturated with a dentine bonding agent and resin. Int Endod J. **29(2)**: 76-83

Machtou P, Amor J, Lumley P (1998) Le System B. *Rev Fr End.* **4(17)**: 27-34

Malagnino V, Cantatore G, Lupol I (1994) Analyse chimique quantitative. Point de fusion and temps de plasticisation des différentes branches de gutta-percha. *Rev Fr Endod.* 6: 136-140

Marciano J, Michailesco PM (1989) Dental gutta percha: chemical composition, X-ray identification, enthalpic studies and clinical implications. *J Endod.* **15(4)**: 149-153

Mulhern JM, Patterson SS, Newton CW, Ringel AM (1982) Incidence of postoperative pain after one-appointment endodontic treatment of a symptomatic pulpal necrosis in single rooted teeth. *J Endod.* **8(8)**: 370-375

Nguyen TN (1991) Obturation of the root canal system. In: *Pathways of the pulp.* Eds: Cohen S and Burns RC. Year Book. **5a**: 219-71. Mosby, St. Louis

Pommel L, Camps J (2001a) Effects of pressure and measurement time on the fluid filtration method in endodontics. *J Endod.* **27(4)**: 256-258

Pommel L, Camps J (2001b) In vitro apical leakage of system B compared with other filling techniques. *J Endod.* **27(7)**: 449-451

Ricucci D, Langeland K (1998) Apical limit of root canal instrumentation and obturation. *Int Endod J.* **31**: 394

Ruddle CJ (2002) Cleaning and shaping the root canal system. In: *Pathways of the pulp.* Eds: Cohen S. and Burns RC. 8th edition, 231-291. Mosby, St Louis

Saw LH, Messer HH (1995) Root strain associated with different obturation techniques. *J Endod.* **21(6)**: 314-320

Schilder H, Goodman A, Aldrich W (1974) The thermomechanical properties of gutta percha, III. Determination of phase transition temperatures for gutta percha. *Oral Surg Oral Med Oral Pathol.* **38(1)**: 109-114

Shabahang S, Goon WWY, Gluskin AH (1966) An in vitro evaluation of Root ZX electronic apex locator. *J Endod.* **22(11)**: 616

Sjorgen U, Figdor D, Persson S, Sundqvist G (1997) Influence of infection at the time of root filling in the outcome of endodontic treatment of teeth with apical periodontitis. *Int Endod J.* **30(5)**: 297-306

Southard D, Rooney T (1984) Effective one-visit therapy for the acute apical abscess. *J Endod.* **10**: 580-583

Torabinejad M et al (1994) Effectiveness of various medications on postoperative pain following root canal obturation. *J Endod.* **20(9)**: 427-431

Telli C, Gulkan P, Gunel H (1994) A critical revaluation of stresses generated during vertical and lateral condensation of gutta percha in the root canal. *Endod Dent Traumatol.* **10**: 1-10

Wolcott JF. Himel VT, Hicks ML (1999) Thermafil retreatment using a new System B technique or a solvent. *J Endod* **25(11)**: 761-764

This article was first published in 2004 as 'Obturation canalaire et préservation radiculaire' in *Réalités Cliniques* 15(1): 33-53

This article is equivalent to one hour of verifiable CPD. Answers can be posted to Endodontic Practice Verifiable CPD, FMC, 1 Hertford House, Farm Close, Shenley, Herts WD7 9AB, faxed on 01923 851778 or emailed to debbie.levey@fmc.co.uk.

Your name:..

Subscriber no: ....
REF: EP/CANTATORE/FEB06

GDC registration no: ....

Address: ....

Q1 Which of the following is not an objective of root canal preparation as described by LS Buchanan?
a) Continuous tapering preparation, wide apically and narrow coronally
b) Maintenance of original anatomy
c) Preparation to a predefined taper
d) Maintenance of original foramen diameter

Q2 In the opinion of the author, which of the following comments regarding the apical extent of obturation are correct?
a) Working short of the radiographic apex can leave pulpal tissue in the canal
b) Apex locators allow the clinician to determine the position of the apical foramen accurately
c) Retreatment of 'long' cases are invariably due to inadequacies in shaping and cleaning procedures
d) All of the above

Q3 Which of the following comments regarding the viscosity of gutta percha products are correct?
a) The high viscosity of Thermafil gutta percha allows it to flow when high condensation forces are applied
b) The low viscosity of gutta percha as used in the System B technique allows it to flow when low condensation forces are needed
c) The low viscosity of Thermafil gutta percha allows it to flow with little condensation forces
d) The high viscosity of gutta percha as used in the System B technique allows it to flow when low condensation forces are used

Q4 In making a decision to use System B or Thermafil, which of the following should be considered?
a) System B is more useful in long canals with minimal taper
b) Thermafil is more useful in short canals with larger taper
c) Thermafil is more suitable in long narrow canals prepared to minimal taper

HENRY SCHEIN CPD section supported by an educational grant from HENRY SCHEIN