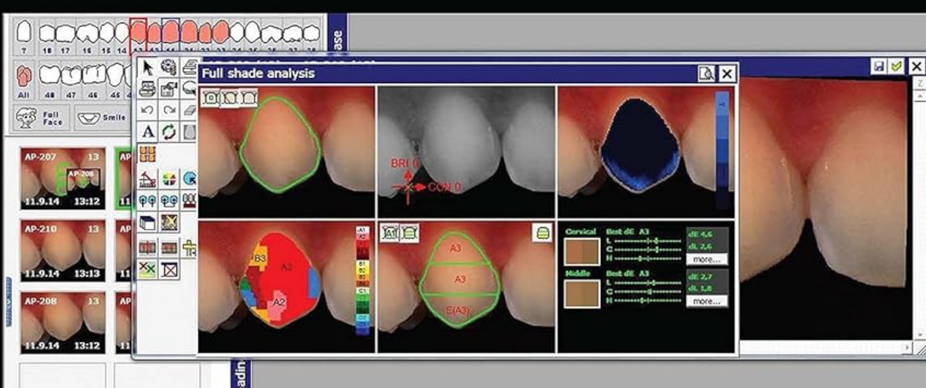
Debonding and Fixed Retention in Orthodontics

An Evidence-Based Clinical Guide

Edited by
Theodore Eliades • Christos Katsaros



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Edited by

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Preface

The completion of orthodontic treatment includes two important phases, which have not received the proper attention in the broader orthodontic literature and are therefore highly individualized, empirically driven and with limited evidence: debonding and fixed retainer bonding.

The first includes the detachment of the orthodontic appliance from the enamel and the subsequent grinding of the adhesive layer (or, more recently, the thick composite attachment block used in aligners). This stage entails a relatively large number of materials and processes that are influenced by the bonding process, because etching-mediated bonding results in a more cumbersome and catastrophic debonding procedure than glass-ionomer bonding, for example. Depending on the composition of the appliance used, this process includes using debonding pliers or ultrasound, laser or heat probes to detach the bracket; many types of burs with different cutting efficiencies in slow- or high-speed handpieces and an array of polishing tools are also used.

Fixed retainer bonding includes many types of wires and configurations bonded with various types of composite resins requiring different handling, even for the same materials. Some side effects have been reported related to the placement technique or the wire activation over time: the coaxial wires used have a significant resilience and therefore store a recoverable elastic deformation, which is then given back to the wire-adhesive-tooth complex, resulting in either fracture of the wire-adhesive interface or unwanted tooth movement.

For this plethora of materials, instruments and handling modes, the information transferred to the trainee or practicing clinician is often dictated by the bias of the supervising instructor for postgraduate students or the content of relevant weekend courses – the sort that have saturated the professional community – rather than the result of an evidence-based approach.

The objective of this textbook is to provide succinic and clinically relevant information on the underlying mechanisms of success or failure for these two fundamental phases of treatment. The book is structured around two axes: debonding and resin grinding, and fixed retainer placement.

The first section covers aspects of the topic that have not yet been found in relevant texts, including methods of appliance removal, cutting efficiency of burs, grinding and enamel effects, complicated interfacial characteristics of attachments with enamel and aligners, airborne pathogens and aerosol produced during resin grinding, and future materials utilizing biomimetic approaches for bonding, among others.

The second section provides an analysis of the materials utilized in fixed retainer bonding, with emphasis on resin, wires, their effect on material deformation during mastication or placement, and release of bisphenol-A from fixed retainer resin adhesives, as well as clinical effectiveness and unwanted effects of fixed retainers on tooth position.

We hope the book will serve as a source of information serving education and practice alike.

Theodore Eliades
Christos Katsaros

Section A

Debonding

1

Cutting with Rotating Instruments and Cutting Efficiency of Burs

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1.1 Introduction

The retention phase is a crucial part of orthodontic treatment. Its importance keeps increasing since patients look for a long-lasting ‘perfect’ result for aesthetic reasons, even though some degree of relapse is always expected. For this reason, life-long retention is more commonly advised every day by clinicians (Padmos et al. 2018).

Many studies have analysed the retention phase in terms of stability, retention material, adhesion, clinician and patient preference and hygiene (Al-Moghrabi et al. 2018; Eroglu et al. 2019; Gugger et al. 2016; Sifakakis et al. 2017), but none of the literature has focused on the consequences of retention on the enamel. Unlike bracket debonding, the detachment of lingual retainers is usually accidental and may be caused by excessive force, adhesive material wear or retainer rupture. The enamel could be altered due to the applied load that caused the rupture in the adhesive interphase or the removal of remaining adhesive or retainer materials (Ryf et al. 2012).

Debonding and Fixed Retention in Orthodontics: An Evidence-Based Clinical Guide, First Edition. Edited by Theodore Eliades and Christos Katsaros.

Cleaning and polishing procedures for remnants of adhesive materials are as variable as retention protocols. No consensus has been reached on the ideal protocol for adhesive removal (Janiszewska-Olszowska et al. 2014). The various techniques include using hand instruments, rotatory instruments (high- and low-speed), sandblasting, ultrasound and bur and disc materials including tungsten carbide burs, diamond burs, composite burs, rubber burs and Sof-Lex discs (Eliades 2019; Janiszewska-Olszowska et al. 2015; Shah et al. 2019). This is a critical moment, as the aim is to remove the material with no or minimal damage to the enamel structure and without overheating the pulp due to friction caused by the instruments. To do so, it is extremely important to carefully select the burs and rotary instruments to be used. For this reason, it is important to have a good understanding of the cutting efficiency of the burs, which type of bur is most suitable, the bur's longevity and the maximum number of uses due to loss of effectiveness. It is also important to take into account the characteristics of the rotating instruments: rotational speed, torque or power, water spray coolant, etc., to avoid damaging the tooth.

In this chapter, we will discuss aspects of the retention phase concerning enamel preservation and the consequences of temporarily adhesive procedures, such as appliances bonding, on the enamel surface. We will analyse the repercussions of adhesive procedures for retention materials, especially considering that life-long retention may require one or more rebonding procedures (Jin et al. 2018). We will also deal with the correct selection of burs for the removal of cement from brackets and fixed retainers; the subsequent final finishing with polishing tools to help recover the enamel aesthetics; and the most advisable protocol for removing fixed retainers, whether for final removal or for a rebonding procedure.

1.2 Enamel Surface and Damage Associated with Debonding Techniques: Burs and Polishing

Thanks to advanced microscopy technology and mineral property analysis techniques, the composition of enamel and its properties before and after adhesive treatments have been widely studied. The vast majority of studies are based on the vestibular surface because there is significant concern about enamel preservation due to aesthetic concerns. However, more aggressive bonding techniques are often used on the lingual surface because this surface does not have aesthetical importance. Such studies are usually done on labial surfaces; it is not common to do them on lingual surfaces.

An *in vitro* study using a scanning electron microscope (SEM) found an important difference between the two enamel surfaces. The lingual surface appears to be smoother, with smaller micropores and a less pronounced wavelike appearance after conditioning, which resulted in less mechanical interlocking in the enamel-bonding interphase and, thus, lower shear bond strength (SBS) values and greater tooth damage compared to the buccal side (Brosh et al. 2005). This interesting data is rarely discussed when adhesion protocols for retainers or lingual brackets are presented.

Sufficient bonding strength, easy debonding and limited damage to the enamel surface are critical factors in orthodontics (Shinya et al. 2008). A lower enamel Adhesive Remnant Index (ARI) after cleaning of residual adhesive corresponds to less damage to the enamel surface (David et al. 2002; Fjeld and Ogaard 2006). Removal systems are important not only for enamel preservation after appliance removal but also in lingual retention: the polishing phase is crucial for patient comfort because studies show that patients' tongues can detect changes in surface roughness (SR) of less than 1 μm (Jones et al. 2004). Furthermore, the smoother surface helps reduce the amount of bacterial plaque deposited.

Before selecting instruments, some basic concepts related to burs must be considered: cutting, grinding, and finishing and polishing actions. *Cutting* is a unidirectional action related to instruments with blades, such as tungsten carbide burs. Depending on the number of blades, the bur will have more of a cutting or polishing function. Also, if we use a low-speed handpiece, by allowing a change of rotation, we can obtain a greater polishing effect rather than cutting. It has been seen that tungsten carbide burs can leave a regular pattern on the enamel structure (Figure 1.1). The *grinding* action is responsible for removing small particles from the surface by the effect of abrasive wear, and their action is unidirectional. Diamond burs are an example (Figure 1.2). Different types of diamond burs are available depending on the size of the component particles. During the *finishing and polishing* phase, the use of tungsten carbide burs with more blades or diamond burs with fine grit is

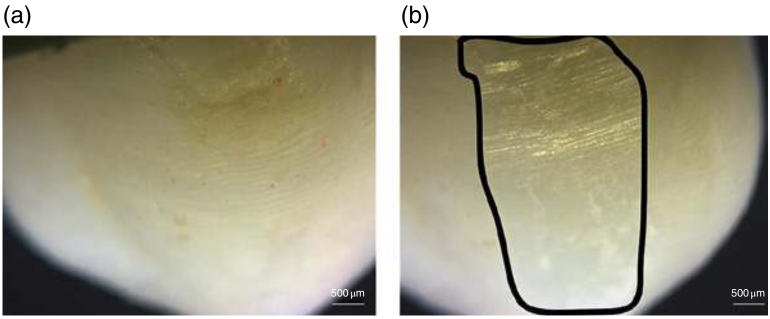

Figure 1.1 (a) Natural tooth; (b) tooth ground with a carbide bur.

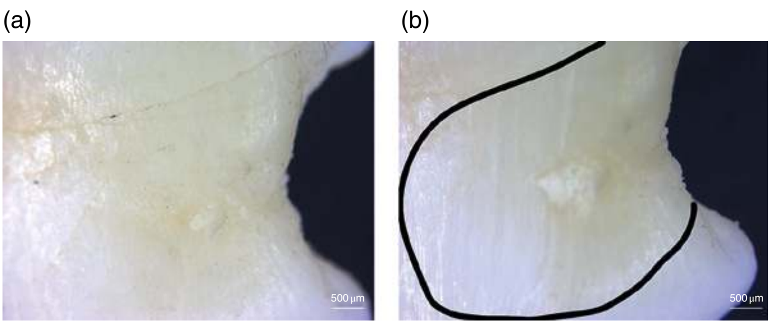

Figure 1.2 (a) Natural tooth; (b) tooth ground with a diamond bur.

indicated to give the final texture to the surface. Polishing gives a gloss to the enamel, which regains its usual brightness after the cement is removed and becomes smooth and homogeneous. This final part of the polishing process is usually carried out with abrasive instruments such as rubber cups, discs, strips and fine-grained polishing pastes (Anusavice 2013).

To remove cement properly, it is important to take into account the *cutting efficiency* of the burs, which is defined as the maximum capacity to remove dental tissue with the minimum effort during a specific period of time (Choi et al. 2010). It is measured and evaluated by calculating the amount of substrate removed (by weight or length of the cut) in a given time. Many studies have observed a reduction in cutting efficiency after repeated use of burs (Bae et al. 2014).

This reduction of cutting efficiency is associated with factors such as (i) wear of the burs due to use and friction, (ii) debris clogging the bur surface, and (iii) the procedures for cleaning, disinfecting and sterilizing the burs. Some studies have determined that cutting efficiency decreases between the first and the sixth sterilization cycles (Bae et al. 2014; Emir et al. 2018; Regev et al. 2010). Firoozmand et al. (2008) determined that the lifetime of a bur is five uses, since after that it is difficult to guarantee a proper and efficient cut. These results were confirmed by Emir et al. (2018).

1.2.1 Design and Type of Burs

1.2.1.1 Diamond Burs

The selection of diamond burs should focus on constant cutting efficiency throughout their life span because studies have shown that these burs tend to lose their efficiency due to use (Bae et al. 2014; Emir et al. 2018; Prithviraj et al. 2017). One of the factors related to the reduction in cutting efficiency is the pull-out of diamond chips (Bae et al. 2014; Pilcher et al. 2000; Prithviraj et al. 2017) (Figure 1.3).

Manufacturers use various methods to adhere abrasive particles to the bur shaft, such as electrodepositing a nickel coating on diamond chips (Ben-Hanan et al. 2008; Siegel and Anthony Von Fraunhofer 1998), electrodepositing a chrome-nickel coating (Regev et al. 2010; Siegel and Anthony Von Fraunhofer 1998), sintering, microabrasion (Prithviraj et al. 2017; Siegel and Anthony Von Fraunhofer 1998; Siegel and Von Fraunhofer 1996) and chemical vapour deposition (Jackson et al. 2004). The quality of diamond burs is based on the concentration of abrasive particles and the capacity of the adhesive system to retain the diamond particles during continuous use.

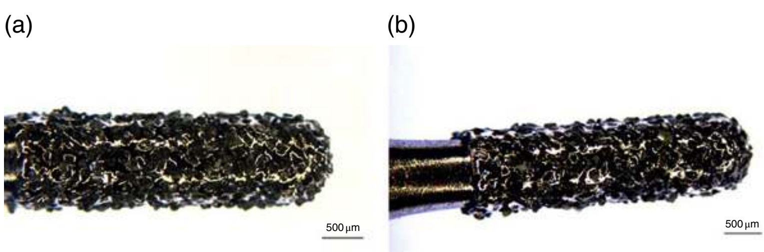

Figure 1.3 (a) Diamond bur before use; (b) diamond bur after use.

The diamond particles used in burs vary between manufacturers, and the primary characteristics are (i) whether the diamonds are natural or synthetic, (ii) their size and shape, and (iii) the individual features of burs. Natural diamonds have more irregular shapes than synthetic ones, which facilitates their deposition in a nickel or chrome-nickel coating matrix. The size of the diamond chips determines the thickness and category of the burs: ultrafine, fine, medium or coarse (Siegel and Anthony Von Fraunhofer 1998). In cutting efficiency studies, medium grit (120–140 μm) or coarse grit (150–160 μm) burs are generally used. Fine and ultra-fine grit burs are not usually evaluated in the literature, as their use is more indicated for finishing and polishing.

The cutting and grinding actions of diamond burs are caused by friction. Every movement of the bur in both directions removes tissue with the abrasive action of the sharp edges of the diamond chips (Figure 1.4).

1.2.1.2 Tungsten Carbide Burs

Tungsten carbide burs are composed of 8 to 40 blades (Figure 1.5); the most frequently used have 8, 12, 20 or 40 blades and are indicated for contouring and smoothing various dental materials and structures (Jefferies 2007). These burs generally are characterised by their hardness and cutting edge, but they wear out with each use and are also fragile and susceptible to fracture (Di Cristofaro et al. 2013).

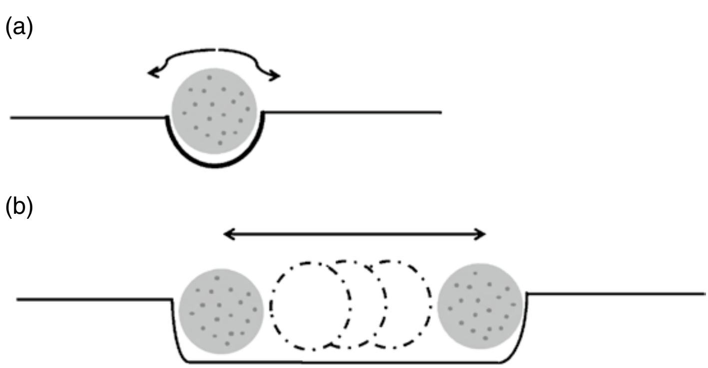

Figure 1.4 Grinding action by diamond burs. (a) During the first step in the grinding process, the bur starts to remove tissue. (b) Every movement of the bur in both directions removes tissue by abrasive action.

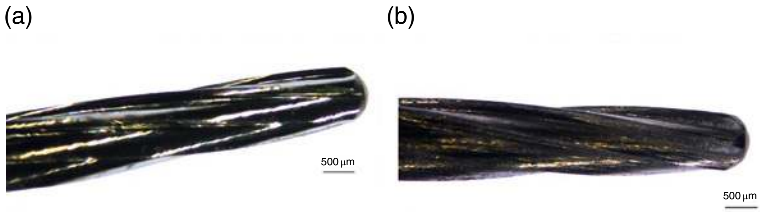

Figure 1.5 (a) Carbide bur before use; (b) carbide bur after use.

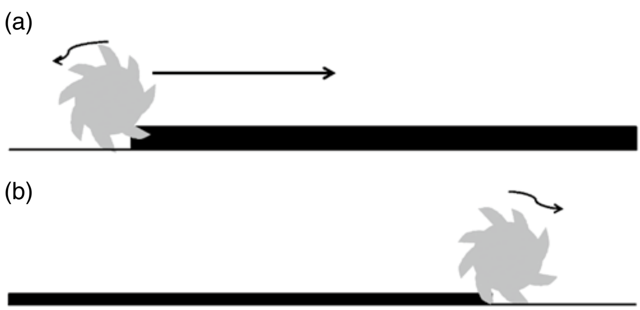

Figure 1.6 (a) Cutting action in a clockwise direction; (b) polishing action in a counterclockwise direction.

Tungsten carbide burs have a bidirectional cut so that when the burs are rotated in a clockwise direction, they have a cutting action. In a counterclockwise direction, they have a polishing action such that a regular pattern is observed on the tooth structure, corresponding to the ordered arrangement of the blades on the bur (Figure 1.6).

Burs with fewer blades are normally used for cutting and grinding, while those with more blades are used to finish polishing and provide texture, as they have a less aggressive effect on the enamel surface.

Carbide burs are considered the gold standard in the literature for removing orthodontic cement during the debonding procedure because they are faster and more effective than other tools that can be used in this stage. But there is always a risk of removing part of the enamel and altering the external surface, in which case the enamel will not recover its original external roughness (Bosco et al. 2020).

1.2.2 Cutting Efficiency

Cutting efficiency can be defined as the amount of substrate removed in a specific period. A long cutting time means lower cutting efficiency (Bae et al. 2014).

This efficiency depends on several factors, such as (i) the type of burs used (diamond or carbide); (ii) the cutting instrument, which may be a turbine or an electric motor handpiece; (iii) the water flow (to remove debris that is clogging the burs and control the intra-pulp temperature); (iv) the force applied by the operator; and (v) the substrate.

1.2.2.1 Diamond and Carbide Burs

Studies usually compare carbide burs with each other and with diamond burs. Diamond burs are also compared with each other, comparing different particle sizes, usually medium (120–140 μm) or coarse (150–160 μm) grit, with different designs (channelled or conventional) and shapes (chamfered or thin taper).

In general, carbide burs have good cutting efficiency; it is greater in burs with deep angles and sharp edges (Di Cristofaro et al. 2013). Another factor that improves cutting efficiency is a negative cutting angle: it makes the bur more effective because it reduces debris that clogs the bur and interferes with cutting and speed. Some studies observe that carbide burs are faster and more effective than diamond burs (Ercoli et al. 2009); this may be due to their hardness and cutting edge compared to the hardness of the metal that acts as a binder for diamond chips. However, other publications consider diamond burs to have a higher cutting efficiency than carbide burs (Emir et al. 2018).

All diamond burs exhibit similar behaviour: the greatest loss of efficiency occurs between the first and second cuts, after which it decreases progressively (Bae et al. 2014; Pilcher et al. 2000). This is due to wear of the burs during use.

The cutting performance of this type of burs primarily depends on the diamonds. Natural diamonds have irregular shapes with sharper edges, so the most effective burs have a higher proportion of natural diamonds (Prithviraj et al. 2017; Siegel and Von Fraunhofer 1996, 1999). Other factors are the size and diameter of the diamond chips. Larger grit means the bur has greater cutting efficiency. However, studies show that burs with medium and coarse grit often do not differ in their cutting efficiency. This may be because manufacturers assign a category to their burs, such as medium grit; then, when studies analyse the burs with a SEM and measure the diamond chips, the diamonds are observed to be larger and correspond more closely to the coarse size described by the ISO standard (Bae et al. 2014; Prithviraj et al. 2017). In general, these differences between manufacturer classifications and the analysis during studies may be due to the filters used in the manufacturing process to standardise the grit allowing a range of sizes to pass through, so that sometimes particles with greater diameters are introduced.

Cutting efficiency is compromised when diamond chips are pulled out of the binder with which they are attached to the bur shaft rather than by the wear of the diamond cutting edge (Bae et al. 2014; Ben-Hanan et al. 2008; Emir et al. 2018; Prithviraj et al. 2017). The extent to which diamonds can be pulled out is associated with the properties of the metal used as a binder (Bae et al. 2014) or the system used to bond the diamonds to the bur. The chips are less likely to be detached when the binder is more powerful and has higher adhesion properties, and therefore the bur has greater cutting efficiency. It has also been seen that burs that use nickel electroplating have lower cutting efficiency than burs that use a proprietary brazing system (PBS) (Prithviraj et al. 2017). SEM studies of burs processed by means of electrodeposition with nickel have observed that spaces are left by detached diamond chips; in addition, some diamond chips are embedded too far into the metal matrix, leaving fewer cutting edges exposed and providing less area for cutting (Prithviraj et al. 2017). Another factor that can affect cutting efficiency is a secondary effect of spaces left by diamonds when they are clogged with debris. This effect reduces the effective work of the burs, which is why it is important to cool them properly during grinding or polishing so the water removes this debris (Ben-Hanan et al. 2008).

The design and shape of diamond burs also influence their cutting efficiency. Some studies have compared chamfered and thin-taper burs and observed that burs with a larger diameter (chamfered) have a larger cutting area, greater peripheral speed, and higher cutting efficiency than thinner burs (Bae et al. 2014). However, it has been observed that chamfered burs produce a larger temperature increase due to greater friction. Other studies have compared conventional and channelled burs and observed that conventional burs have a higher cutting efficiency than channelled burs (Funkenbusch et al. 2016). It has been seen that grooved burs allow a better distribution of water along the bur between the grooves, providing constant cleaning and reducing clogging debris in the bur, and also achieve faster heat dissipation (Galindo et al. 2004), but no statistically significant differences were observed compared to conventional burs (Ercoli et al. 2009).

The effect of cleaning, disinfecting and sterilisation on the cutting efficiency of burs has also been studied, and some studies concluded that these procedures do not directly affect cutting efficiency (Bae et al. 2014). However, other authors have observed that cleaning and sterilising burs that are used repeatedly improved their cutting behaviour because debris is eliminated during the cleaning procedure (Rotella et al. 2014).

Some studies have evaluated whether bur wear affects the SR the burs cause on the tooth structure or materials as well as cutting efficiency. It seems that the more worn the bur is, the lower the cutting efficiency and SR. The loss of roughness may be heterogeneous, but it can affect the bonding process (Emir et al. 2018). When studying different materials, it is observed that the cutting efficiency of burs used to cut zirconium or lithium disilicate or metals is reduced more rapidly since those materials have harder surfaces than the tooth structure (Emir et al. 2018; Galindo et al. 2004; Nakamura et al. 2015; Siegel and Von Fraunhofer 1996).

In summary, the cutting efficiency of carbide burs is reduced due to wear and tear on the blades (Di Cristofaro et al. 2013). On the other hand, in diamond burs, the factors that influence wear and cutting efficiency are (i) diamond chips being pulled out, (ii) wear of the cutting edges of the diamond chips, (iii) debris clogging the cutting areas, and (iv) wear of the material that acts as a binding agent for the diamond chips on the shank (Ben-Hanan et al. 2008).

1.2.2.2 Rotating Instruments: Turbines and Electric Motor Handpieces

For more than 50 years, turbines have been used in dentistry to grind or polish dental structures and materials because of their performance: (i) they are ergonomic and lightweight, (ii) they are reasonably priced, and (iii) they can quickly remove tooth structure. On the other hand, turbines have these disadvantages: (i) vibration and noise, (ii) the release of aerosols, and (iii) low torque, which causes them to slow down when too much force is detected and decreases cutting capacity – a turbine can even get stuck and stop (Choi et al. 2010; Eikenberg 2001; Ercoli et al. 2009; Kenyon et al. 2005; Rotella et al. 2014) (Figure 1.7).

Figure 1.7 Different types of turbines.

Figure 1.8 Electric motor handpieces.

Electric motor handpieces were developed 20 or 30 years ago. They are characterised by their variable power and higher torque than turbines and therefore maintain their rotation speed with less risk of getting stuck when more force is applied than usual. Other positive aspects of these instruments are that (i) they are quieter and have less vibration; (ii) they release fewer aerosols, reducing the risk of cross-contamination; and (iii) they provide more precise and concentric cuts than turbines. On the other hand, electric motor handpieces weigh more, making them less ergonomic than turbines (Choi et al. 2010; Eikenberg 2001; Ercoli et al. 2009; Kenyon et al. 2005; Rotella et al. 2014) (Figure 1.8).

Studies have been carried out to compare cutting efficiency depending on the cutting instrument used: turbine or electric motor handpiece. All the studies came to the same conclusion – that the electric motor handpiece had a higher cutting efficiency than the turbine – although no statistically significant differences were observed (Choi et al. 2010; Eikenberg 2001; Ercoli et al. 2009; Rotella et al. 2014). All the authors believe the reason is the difference in torque: the high torque of the electric motor handpiece means its rotational speed is not reduced when more force is applied (Choi et al. 2010; Eikenberg 2001; Ercoli et al. 2009; Rotella et al. 2014). Choi et al. (2010) even add that the difference could be related to the increased weight of the electric motor handpiece, which may cause the dentist to apply slightly more force (without being aware of it), making the instrument more efficient.

Not only is the electric motor handpiece more efficient than the turbine, but a smoother surface is obtained. In contrast, rough marks can be seen from the effect of a turbine, which may be related to loss of speed and possible stall caused by low torque (Geminiani et al. 2014).

1.2.2.3 Other Factors Related to Cutting Efficiency

As previously mentioned, various factors reduce cutting efficiency, including water flow, which depends on the instruments, and applied force, which depends on both the instrument and the dentist.

Water flow is a very important factor since it removes debris that may remain attached to the bur and avoids iatrogenic injury caused by heat generated during preparation of the tooth (most of the energy that is not used is transformed into heat). The amount of heat transmitted to the tooth usually depends on the type of bur, applied force, cutting time and rate, cooling technique, speed, and torque of the instrument (Galindo et al. 2004).

Most studies that have measured the effect of water flow on the temperature inside the pulp chamber have observed that grinding does not affect the pulp chamber because the water-flow coolant helps to decrease the temperature and prevent the pulp from reaching a critical temperatures. The water flow indicated in these studies to prevent an increase in pulp temperature is between 25 and 50 ml/min, regardless of whether the bur is made of diamond or carbide. More water is always better to cool the tooth preparation (Ercoli et al. 2009; Galindo et al. 2004; Siegel and von Fraunhofer 2000; Siegel and Patel 2016; Von Fraunhofer and Siegel 2000).

The importance of water flow is based on the number and distribution of water outlets on the instruments (Ercoli et al. 2009; Siegel and Von Fraunhofer 2002). Earlier turbines (and some of today's turbines) had only one water port at the base of the head, so the bur was not fully cooled. Today, electric motor handpieces and modern turbines have three or four water ports (Figure 1.9), increasing the water flow of the entire bur. This allows control over the temperature, increases the

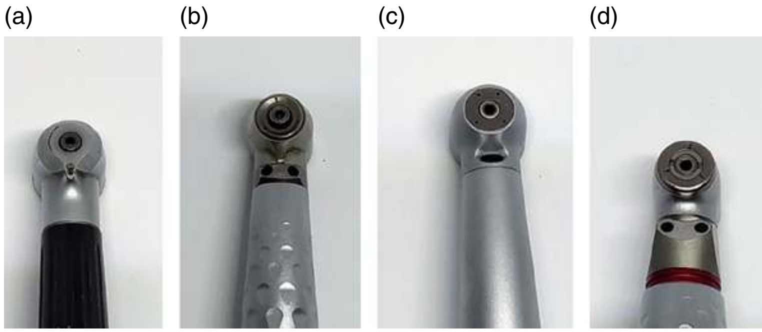

Figure 1.9 (a) Turbine with one water port; (b) turbine with three water ports; (c) turbine with four water ports; and (d) electric motor handpiece with three water ports.

removal of debris, and therefore increases cutting efficiency. Studies have compared the efficiency of dry and wet cutting and concluded that wet cutting increases the cutting rate and removes three times more tissue than dry cutting (Ercoli et al. 2009).

The last important factor related to cutting efficiency is the force applied when preparing the tooth. Different authors have conducted studies with dentists to determine the force they apply. Elias et al. (2003) determined that the force varied between 0.66 and 2.23 N, and Siegel et al. (Siegel and Von Fraunhofer 1997, 1999) concluded that the most effective force for medium-grit burs is 0.92 N. Most literature considers that dentists exert a force between 50 and 150 g when preparing a tooth (Eikenberg 2001; Galindo et al. 2004; Siegel and Von Fraunhofer 1997, 1999). Elias et al. (2003) concluded that the magnitude of the force depends more on the power of the rotating instrument than on the speed of the instrument or outside force applied by the operator. On the other hand, Funkenbusch et al. (2016) consider that greater force applied by the operator generally increases cutting efficiency, so we can observe that there is no consensus about whether force depends more on the instrument or the operator. In summary, all studies consider that as the burs wear out and cutting efficiency is reduced, the force applied by the operator increases, leading to a risk of raising the temperature if there is not proper water flow (Emir et al. 2018; Pilcher et al. 2000; Rotella et al. 2014; Siegel and Von Fraunhofer 1996).