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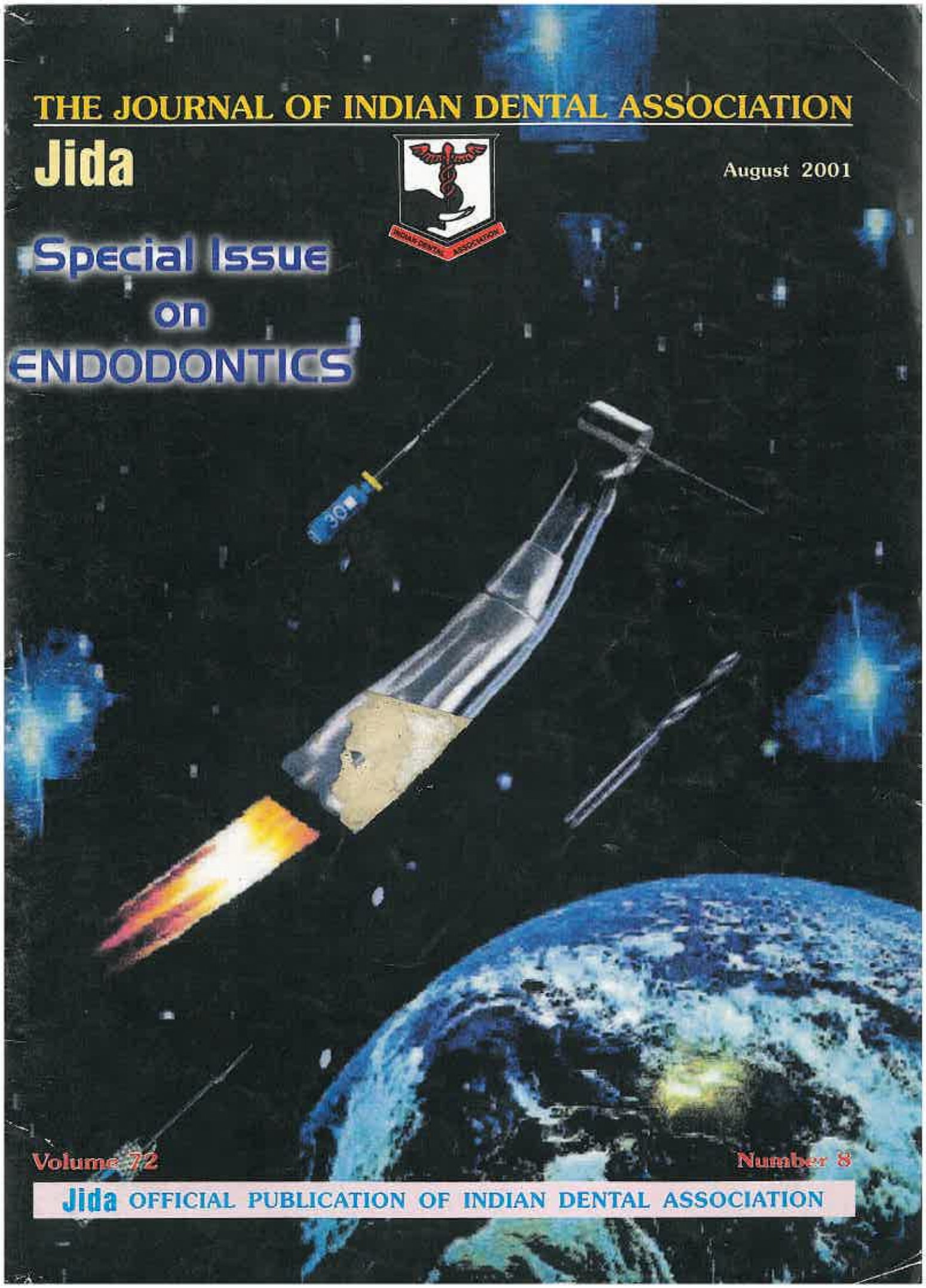

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EQUIPMENT AND INSTRUMENTS

SONICS VERSUS ULTRASONICS

PART-I: MECHANISMS INVOLVED

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INTRODUCTION

Successful endodontic treatment requires accurate diagnosis, proper cleaning, shaping and three-dimensional filling of the root canal system. Striving for this ideal should be the goal of every endodontic professional. The technical demands and level of precision required for successful performance of endodontic procedures have traditionally been achieved by careful manipulation of hand instruments within the root canal space and by strict adherence to the biologic and surgical principles essential for disinfection and healing. In the past two decades, scientific and technologic advances have significantly increased the ability of the modern practitioner to provide higher level of care with the introduction of newer instruments and techniques, at a faster speed than was achievable in the past. Hence, it is essential for the dentist, not only to understand the clinical aspects of root canal therapy, but also to appreciate the range of usefulness and limitations of the instruments involved to produce optimal results consistently. Thus, the clinician must possess a thorough knowledge of the biologic, physical and mechanical properties of instruments, materials and devices that are currently available in the market. This article is an attempt to bridge the lacunae, which is existing between the practicing dentist and the rapid technological advances in both equipment and techniques.

EVOLUTION

Ultrasonic instrumentation was first introduced into dentistry in the form of a drill[1,2] (Catuna, 1953; Balamuth, 1967). Such instruments were used with an abrasive slurry for the preparation of tooth cavities prior to restoration[3] (Postle, 1958). This technique however was superseded by the advent of the high-speed handpiece and a further development took place when Zinner[4] (1955) recorded the use of an ultrasonic instrument to remove deposits from the tooth surface. Johnson and Wilson[5] (1957) improved upon the instrumentation and the ultrasonic scaler became established in the removal of dental plaque and calculus. The idea of utilizing ultrasound in Endodontic therapy was suggested in 1957 by Richman[6], who adapted an ultrasonic scaler for use in apicoectomies; however, its potential was not fully developed until 1976, when Martin[7] developed a commercial system harnessing the properties of ultrasonic energy in the preparation and cleaning of the root canal. Tronstadt et al[8] in 1985, were the first to report on the use of a sonic instrument for Endodontics. These techniques were termed as ***Endosonics*** by Martin and Cunningham, and has now become a well recognized endodontic procedure.

AN INSIGHT

Endosonics, denotes a device which imparts sinusoidal vibration of high intensity to a root canal instrument in the range which is either above that of audible perception, i.e. at ultrasonic frequencies (20-42 kHz) or operate within the arbitrary sonic or hearing range (i.e. below 20 kHz). Both ultrasonic and sonic instruments are, however, similar in design, in that they consist of a driver, at the end of which is clamped an endosonic file usually at an angle of 60^0-90^0 to the long axis of the driver. It is the oscillatory pattern of the driver that determines the nature of movement of the attached file. Endosonic instrumentation differs from hand and rotary instrumentation since the cutting of dentin is facilitated by a mechanical device that imparts a sinusoidal motion to the instrument by the transfer of vibrational energy along the shaft.

The Physics behind Ultrasonics:

There are two basic methods of producing ultrasound. The first is Magnetostriction, which converts electromagnetic energy into mechanical energy. A stack of magnetostrictive metal in the handpiece is subjected to a standing and alternating magnetic field, as a result of which, vibrations are produced. The second method is based on the Piezo-electric principle. A crystal is used which changes dimensions when an electrical charge is applied. This crystal deformation is converted to mechanical oscillation with no production of heat.

The Magnetostrictive units have the disadvantage, when compared with the Piezo-electric, that the stack generates heat and must be cooled. This means tubing is required to carry water to the handpiece, and if the irrigant is sodium hypochlorite, then the water has to be led away by more tubing, after cooling the stack. A separate source of tubing carries the sodium hypochlorite to the head of the handpiece. Both these types work at ultrasonic frequencies and exhibit similar patterns of file oscillation.

At the ultrasonic frequencies used, the main driver oscillates in a true longitudinal manner, and as it moves back and forth a transverse wave (Fig. 1) is generated along the length of the endosonic file[10]. This transverse oscillation is characterized by a series of *Nodes* and *Antinodes* along the length of the file, the nodes representing sites of minimum oscillation or displacement of the file and the antinodes representing sites of maximum oscillation or displacement. The tip of the file that is totally unconstrained will oscillate with the greatest displacement from rest. It is this motion of the file that almost certainly causes abrasion (filing) of the canal walls when the instrument is moved vertically within the canal.

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The energy contained in the transverse oscillation of the file is low, however, compared to that of the driver, consequently, if the file is constrained within a tightly fitting canal the oscillatory pattern will be reduced or even eliminated[10]. This is inefficient and more likely to occur in curved canals than straight ones. Furthermore, the tip of the file is particularly prone to this form of constraint.

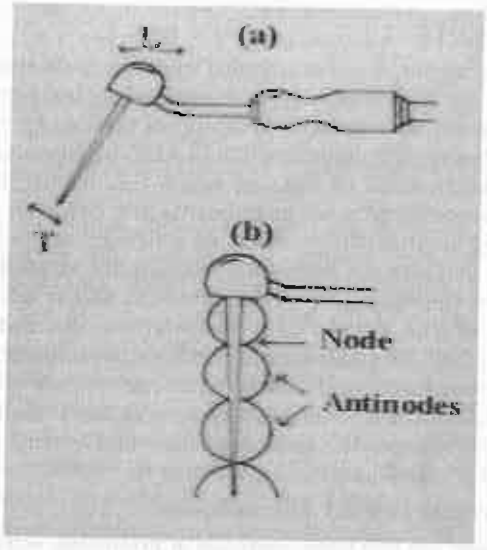

Fig. 1. The Oscillation of the Ultrasonic instrument.
(a) The main longitudinal oscillation (L) occurs along the main axis. The file is at an angle to the main instrument, and subsequently a transverse motion (T) is set up along its length.
(b) The transverse oscillation of the file consists of antinodes, where the greatest oscillation occurs, and Nodes, where minimal oscillation is present. The tip of the file that is unconstrained exhibits the greatest oscillation.

It is apparent that transverse oscillation is not a particularly effective mode of movement for an endodontic procedure, as it may result in irregular cutting of dentin or uncontrolled filing in the apical third of the root canal – dependent upon whether the file is constrained or free within the canal. A true longitudinal action of the file would be an advantage, as this would enable a filing action to take place along the total length of the root canal.

The Physics behind Sonics:

Sonic instruments rely on the passage of pressurized air through the instrument handpiece in order to produce oscillation of the working tip. Two such types are in current use, operating at either around 3-6 kHz or 16-20 kHz. The sonic instruments have a main driver, which in contrast to the ultrasonic driver produces an elliptical pattern of oscillation during activation. When the attached file is operated in air without any physical constraint, it sets up a circular motion characterized by a single antinode at the tip and a node near the driver. The action of the driver imparts both a vertical and lateral component to the action of the file. When the file is constrained within a root canal, however, this lateral component is essentially eliminated, and a true vertical or longitudinal file movement remains[10] (Fig. 2). This difference is oscillatory pattern may explain the reportedly superior efficiency of the sonic instrument during clinical use[11].

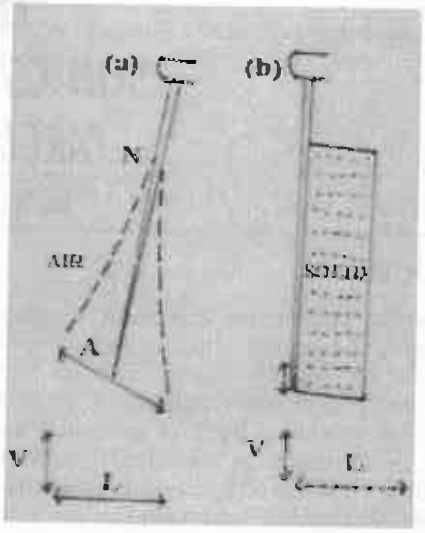

Fig. 2. The Oscillation of the Sonic instrument.
(a) In air the file oscillates with a single large antinode (A) at the tip, with the node near to the driver (N). This oscillation has a large lateral component (L) with a small vertical component (V).
(b) When the file contacts a solid boundary then the lateral component (L) is eliminated leaving a vertical motion only.

BIOPHYSICAL EFFECTS OF ENDOSONICS

Cavitation:

Cavitation is defined as the growth and subsequent violent collapse of a small gas filled pre-existing inhomogeneity in the bulk fluid[12]. When a vibrating object is immersed in a fluid, oscillations are set up in the fluid, which cause local increases (compression) and decreases (rarefaction) in fluid pressure[13]. During the rarefaction

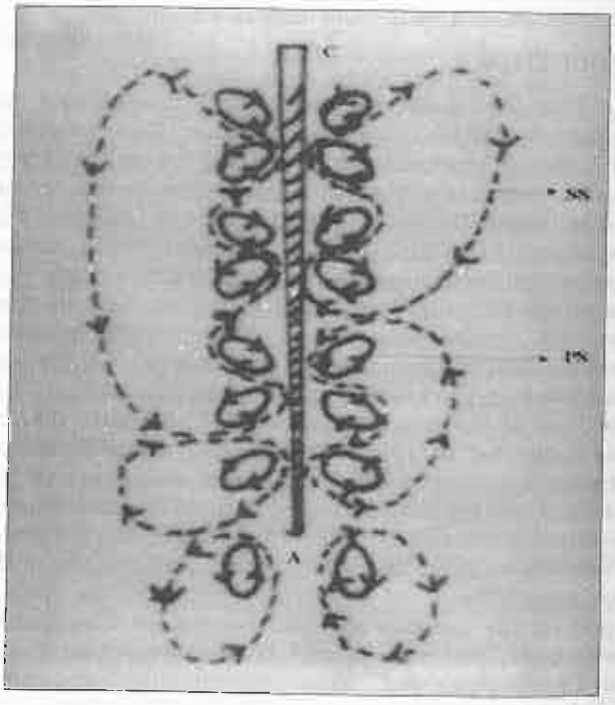

Fig. 3. Diagrammatic representation of Acoustic Streaming
C – Coronal end of File. A – Apical end of File. PS – Primary Streaming. SS – Secondary Streaming.

phase, at certain pressure amplitude, the liquid can fail under acoustic stress and form cavitation bubbles. During the next positive pressure phase, these primarily vapor filled cavities implosively collapse, producing radiating shock waves.

Cavitation has been shown to be useful in the removal of tooth deposits during operation of the ultrasonic scaler, as the scaler has a larger surface area and displacement amplitude, and thus is able to generate the threshold acoustic pressure amplitude necessary to induce cavitation. Although it is theoretically possible that cavitational activity occurs also around the oscillating endosonic file, it is highly unlikely that a confined area such as a root canal would increase the probability of cavitation inception[12]. There are several reasons for this.

- The threshold power setting at which this phenomenon would occur is beyond the range that is normally used for endodontic purposes.
- Cavitation inception depends on free displacement amplitude of the file. This would be impossible to achieve during instrumentation, as damping of the displacement amplitude is inevitable when the file contacts the canal walls.
- The conditions under which a boundary would enhance acoustic cavitation is one in which there would be a reflection of acoustic energy from the boundary with such a phase change as to lead to generation of standing waves within the volume of the liquid being examined. Since it is necessary for such a boundary to be at least one half wavelength away, and the wavelength of sound in water at a frequency of 25kHz is 6cm, the production of standing waves (and thus cavitation enhancement due to doubling of the acoustic pressure amplitude) would not be possible within a root canal. A root canal has thus to be at least 6 cm in diameter for standing waves to form, which one does not encounter clinically.

Acoustic Streaming:

Acoustic streaming is defined as the generation of time independent, steady unidirectional circulation of fluid in the vicinity of a small vibrating object[14]. When a vibrating file is immersed in a fluid, the file is observed to generate a streaming fluid comprising two components: the *Primary field* consisting of rapidly moving eddies in which the fluid element oscillates about a mean position, and a superimposed *Secondary field* consisting of patterns of relatively slow, time independent flow. Characteristically the fluid is transported from the apical end to the coronal end. These flows of liquid have a small velocity, of the order of a few centimeters per second, but because of the small dimensions involved the rate of change of velocity with distance from the file is high. This results in the production of large hydrodynamic shear stresses around the file, which are more than capable of disrupting most biological material.

In a endosonic file the greatest shear stresses will be generated around points of maximum displacement, such as the tip of the file and the antinodes along its length and it is probable that will also be important in moving the associated irrigant around the canal so that maximum benefit is achieved from the chemical irrigant. Although either type of endosonic instrument (sonic and ultrasonic) is capable of producing acoustic microstreaming, the clinical efficiency of such forces will be dependent upon the amount of file constraint that occurs – especially in tight or curved canals[15].

IRRIGANTS

The four goals of irrigation that one must take into account are lavage of debris, tissue dissolution, antibacterial action and lubrication. Although preliminary debridement is accomplished with hand instruments, Shih and associates[16] demonstrated that canal irregularities might contain organic tissue that could not be mechanically removed. This was corroborated by Moodnik et al[17], showing irregularities with debris and pulp tissue that current endodontic instrumentation could not remove. Spangberg and co-workers[18] pointed out that residual infection is due to difficulty in removing this substrate for microorganisms. One must therefore rely on lavage and some means of chemical dissolution of the remaining tissue. Consequently, the ability of the irrigant to act as an effective organic solvent is of clinical importance. This enhancing feature of the irrigant is one dimension of the improved physical chemistry of irrigation within the multidimensional endosonic system. There are several important aspects of irrigating root canals: these are the types of irrigant used, the quantity of irrigant, temperature of the solution and its shelf life.

The type of irrigant that should be used is agreed by most authorities to be Sodium hypochlorite. It fulfils most of the requirements of an ideal irrigant by being bactericidal and capable of dissolving organic debris. An agreement has not been reached on the optimum concentrations, although Martin and Cunningham[19] have recommend 2.5 per cent. The problem with sodium hypochlorite is that it is corrosive to metals and makes the maintenance of endosonic units difficult and time consuming. Yet, it remains the most recommended irrigant due to its synergistic effect with endosonics[20].

Baker and associates[21] showed that the flushing quantity of irrigant was the paramount factor in cleaning the canal, irrespective of the type of irrigant. The phrase 'copious irrigation' is often found in the literature, yet this can be misleading as it is the quantity of irrigant that circulates to and from the apical limit of the root canal that is important. It has been found that with an irrigant flow of 20 ml per minute, it takes around 30 seconds for the irrigant to reach the most apical extent of the canal space. This fact reiterates the need for an effective and swift method of irrigation and debridement of the root canal space. Thus, an irrigant with solvent qualities used in large volumes and enhanced by ultrasonic activation and mechanical energizing will be superior to conventional irrigant action.

The temperature of the sodium hypochlorite is relevant because if it is heated from 21° to 37°C its ability to dissolve collagen is enhanced[22]. It has been pointed out that with continuous irrigation there is no heating effect

in the canal, therefore it may be of benefit to preheat the irrigant in the reservoir within the endosonic unit. However sodium hypochlorite warmed to 37°C remains stable for no longer than 4 hours before breaking down[23]. The shelf life of NaOCl varies with the concentration being employed. For example it has been found that the stable shelf life of 5.25% NaOCl is 10 weeks, whereas 2.6% and1.0% remain stable for only 1 week after mixing with water[24].

CONCLUSION

In an ultrasonic instrument the main driver oscillates in a true longitudinal manner, and as it moves back and forth a transverse wave is generated along the length of the file with the formation of a series of *Nodes* and *Antinodes* along the length of the file. However, in a sonic instrument a circular motion characterized by a single antinode at the tip and a node near the driver is generated. The action of the driver imparts both a vertical and lateral component to the action of the file. Thus, when the file is constrained within a root canal, this lateral component is essentially eliminated, and a true vertical or longitudinal file movement remains. This difference is oscillatory pattern may explain the reportedly superior efficiency of the sonic instrument during clinical usage.

Contrary to earlier reports, it is highly unlikely that a confined area such as a root canal would increase the probability of cavitation inception. Recent research has shown that the hydrodynamic shear stresses caused by the acoustic streaming fields are responsible for many of the beneficial effects attributed to the use of endosonics.

Irrigants play a crucial role in both short and long term success of endodontics through their debriding and antimicrobial action. Sodium hypochlorite when activated with endosonics makes a potent synergistic combination for the efficient debridement of the pulp space.

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