

Efficacy of ultrasonic cleaning

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Resin blocks containing simulated root canal spaces were compared with extracted teeth as models for measuring the efficiency of endodontic debridement with hand instrumentation, ultrasonication, or a combination of both techniques. Canal spaces were filled with radioisotope-laden gelatin, and the loss of radioactivity was measured after treatment. No significant differences in efficiency of debridement were observed in teeth prepared with hand instruments or ultrasonics alone; both techniques reduced radioactivity by between 77% and 79%. Ultrasonication after hand instrumentation was the most efficient method; it reduced radioactivity in the teeth and blocks by 88% and 92%, respectively.

Debridement of the root canal system is a critical phase of endodontic therapy.^{1,2} Its purpose is the total removal of vital pulp tissue, necrotic debris, and microorganisms from the involved tooth before obturation. As important as debridement is to successful root canal treatment, current techniques to determine whether it has been achieved are inadequate.

A clinical method for determining that the root canal system is adequately debrided has been the observation of clean, white dentin shavings on the flutes of the reamer or file.³ However, if the root canal system is flooded with irrigation solution during instrumentation, the desired shavings become an unpredictable clinical paste that does not suggest the quality of total debridement.

In vitro evaluation standards have included use of radiopaque medium, determination of numbers of microorganisms, radioisotope procedures,

photography, and light microscopy.⁴⁻¹⁰ Scanning electron microscopic studies also have been used to evaluate different techniques of debridement and instrumentation.^{11,12} McComb and Smith¹¹ found that extracted, single-rooted teeth instrumented according to accepted clinical procedures produced a canal wall that was smeared and often packed with debris. This loosely attached layer was shown to contain not only dentin but also necrotic and viable tissue, remnants of odontoblastic processes, pulp tissue, and bacteria. In addition, the cleaning properties of various irrigating solutions have been studied.¹³⁻¹⁸

Weine and others^{6,7} used clear resin blocks containing simulated pulp canal spaces and studied the effect of instrumentation on canal contours. These blocks were also recommended as educational tools for visualization of endodontic procedures. Although visualization is help-

ful for teaching purposes, it does not appear to be satisfactory when applied to debridement techniques. However, the use of resin blocks as models of pulp canal spaces along with a quantitative measuring procedure using, for example, radioactively labeled debris material, may be more helpful in endodontic research.

The purpose of this study was to compare the debridement of simulated pulp canal spaces in resin blocks with that in natural teeth. With the use of radioactive-laden gelatin for quantification, the debridement efficacy of hand instrumentation, modified probe sonication, and a combination of both techniques was compared.

MATERIALS AND METHODS

Thirty single-rooted mandibular premolars and 30 resin blocks containing simulated pulp canal spaces

were selected. After the teeth were radiographed from the mesial side to verify the absence of multiple canals, standard occlusal access openings were made and the pulp tissue was removed with fine broaches. The teeth were placed in an ultrasonic unit (L and R Manufacturing Co., Kearny, NJ) containing a solution of 5.25% sodium hypochlorite, activated for 15 minutes to remove the pulp remnants, hand washed in tap water, and rinsed in distilled water for one hour in the ultrasonic unit. The working length of the canals was determined visually by inserting a no. 15 K-file to the point of exit and subtracting 0.5 mm. The root apices were sealed with sticky wax and the apical surfaces were covered with boxing wax to reduce isotope contamination of the tooth surfaces. To prefill the dentinal tubules, hot gelatin was injected into the teeth, allowed to cool for 30 seconds, and removed from the main pulp canal space by absorption to paper points.

The resin blocks were reduced in width to fit into counting tubes. Simulated periapical lesions that were included in the resin blocks were eliminated by horizontal sectioning. To provide adequate space for manipulation, the canals were enlarged to accommodate a no. 25 K-file to within 0.5 mm from the visualized apex. Sticky wax and boxing wax were then applied in a fashion similar to that used for the natural teeth.

The teeth and resin blocks were then injected with hot gelatin containing ^{125}I -albumin, 3.48 Ci/ml, and allowed to cool to room temperature. To establish experimental controls, the radioactivity of all specimens was determined with a gamma

scintillation radiation counter. The gel volumes of the resin blocks and teeth were calculated using the measurement of specific activity of the radioactive gelatin. The mean volume of gelatin per block was $19.58 \pm 2.40 \mu\text{l}$ and in the prefilled teeth it was $18.34 \pm 8.05 (\bar{X} \pm \text{SD})$. In a pilot study with 40 nonprefilled teeth, the mean volume of gelatin was $88.2 \mu\text{l}$; furthermore, radioactivity was reduced by a maximum of only 24% by use of either hand instrumentation or hand instrumentation plus sonication. The teeth and blocks were separated into three groups of ten specimens each and debrided by hand instrumentation, ultrasonication, or hand instrumentation followed by ultrasonication.

The experimental procedures were performed by a single operator to minimize clinical variables. In all hand instrumentation the serial preparation technique³ was utilized with 2 ml of distilled water used between each file. The apices were prepared and finished with no. 30 K-files at the working lengths and no. 45 Hedstroem files at the coronal flares. To ensure patency to the working lengths, no. 30 K-files were reintroduced. This was followed by a 5-ml irrigation in a 5-ml disposable syringe with a 25-gauge injection needle. Intracanal drying was accomplished with five paper points.

Ultrasonication of the canals was performed with a Cavitron Ultrasonic Unit fitted with a modified Cavitron insert. The smooth, tapered stainless steel shank of a no. 15 finger plugger, 25 mm in length, was spot-welded to the end of the insert. The probe was introduced to the working length of all specimens, activated, and maintained at this measurement for 20 seconds. While still activated,

the probe was gradually withdrawn through the coronal segments for ten seconds. An effort was made to achieve maximum surface contact with the canal walls by use of lateral pressure in a circular motion during preparation. The canals were then irrigated with 5 ml of distilled water and dried as described for the specimens instrumented by hand.

The hand instrumentation and ultrasonication procedure (group 3) was a combination of the two previously described techniques. To achieve better control, 2 ml instead of 5 ml of irrigation solution was used at the end of hand instrumentation. After completion of the ultrasonication phase, the specimens were irrigated with 5 ml of the irrigant and dried.

After debridement, the wax covering was removed from the teeth and radioactivity was determined in the teeth and resin blocks. The percent loss of radioactivity from that of the controls was calculated for each tooth and block, and the figures were arranged by group. The significance of percent loss in radioactivity was compared using the *t*-test ($[\text{radioactivity before debridement} - \text{radioactivity after debridement}] \div \text{radioactivity before debridement} \times 100 = \text{percent loss in radioactivity}$).

RESULTS

Hand instrumentation and irrigation reduced the radioactivity of prefilled teeth in this study by 78.9% (Table, group 1). Ultrasonication and irrigation reduced radioactivity by 76.6% (group 2). Both of these techniques were not significantly different in efficiency at the .01 level. Ultrasonication applied after completion of hand instrumentation and irrigation reduced radioactivity by

Table 1 • Percent loss in radioactivity in teeth and resin blocks treated by three debridement techniques

Debridement technique	Teeth	Blocks
Group 1: hand instrumentation	78.9%	83.07%
Group 2: ultrasonication	76.6%	57.39%
Group 3: hand instrumentation plus ultrasonication	88.2%	92.24%

88.2% (group 3), which was significantly different from the other groups at the .01 level.

In the resin blocks, hand instrumentation reduced radioactivity by 83.07%; ultrasonication reduced it by 57.39%; and hand instrumentation followed by ultrasonication reduced it by 92.24%. Ultrasonication (group 2) was significantly less efficient than the other two techniques at the .01 level. As in the teeth, hand instrumentation plus ultrasonication was significantly more efficient than hand instrumentation alone in debriding the resin blocks at the .01 level.

DISCUSSION

The physical action of ultrasonication is produced by cavitation of solution.¹⁹⁻²¹ Cavitation is the formation of submicroscopic voids as a result of shearing the fluid medium by the alternating, high-frequency movement of the ultrasonic instrument tip. This movement is produced by a magnetostriction of the metal rod or "stack" in a fixed electromagnetic field, which has an alternating field superimposed on it. As successive waves pass along, the shearing effect develops an enlarged bubble of solution that grows until implosion occurs. The implosion effect creates a void that is filled with the surrounding solution under extreme hydrodynamic pressure, which causes radiating shock waves. These waves can force a solution into all dimensions of a particular system however minute and inaccessible. The effect can create a most effective scrubbing and cleaning mechanism because of the irregular agitation.

The use of ultrasonics in endodon-

tic procedures has received only limited study. Martin¹⁹ inoculated sterile, prepared molars with test organisms and quantitated the bactericidal efficiency of endodontic irrigants when used with ultrasonication. The combined use of ultrasonics and irrigation improved the disinfection and cleaning of the root canal system. Nossek²² evaluated the utility of ultrasonics in canal preparation using visual observation. He reported that ultrasonic instrumentation alone was not adequate for fine, curved canals or for apical preparation. He recommended hand instrumentation to finish the canal preparation. In the present experiment, ultrasonication used after complete hand instrumentation in both resin blocks and extracted teeth produced an 88% to 92% debridement.

In the aforementioned pilot study, the importance of prefilling with a nonradioactive gelatin before collection of experimental data was emphasized. Failure to do so resulted in the retention of at least 76% of the subsequently injected radioactive material after debridement techniques were used. It was concluded that the retained, labeled debris became impacted mainly in the dentinal tubules, beyond the reach of hand instruments or the sonicator probe.

In this experiment we compared the debridement of simulated pulp canal spaces in clear resin blocks to that of prefilled teeth; both the blocks and teeth were filled with radioactive gelatin debris. Because of the varying degrees of dentinogenesis, intracanal fins, and dentinal tubules, extracted teeth presented some difficulties as a model by which

to quantify the efficiency of cleaning. In contrast, resin blocks added a uniformity of shape and volume to the canal space. This was evident in the smaller standard deviation in the canal volume of the blocks as measured from the specific activity of the gelatin content. Gelatin was selected as the quantification medium because it is more difficult to remove from extracted teeth than is intact pulp tissue. This difference may be ascribed to the structural variances between type 1 collagen and elastin (gelatin); namely, type 1 collagen is more fibrous and thus is more apt to remain intact on removal, whereas the elastin (gelatin) tends to fragment, leaving behind residual material. The resin blocks were thus evaluated in the hope of offering an inexpensive, accurate, and rapid method of objectivity in analyzing pulp canal space debridement, and perhaps relating the method to the already demonstrated versatility of the resin in visualizing debridement. The use of resin block simulation offered the additional advantage of eliminating intratubule impaction during quantitative evaluation of debridement. Regardless of the model used, 10% to 30% of the debris still remained in the blocks and teeth.

Throughout this experiment, attempts were made to duplicate clinical conditions as much as possible; consequently, conventional materials and techniques were used. When appraising the combined technique, ultrasonication was measured after hand instrumentation was completed rather than alternating hand instrumentation with the sonicator probe. This seemed to be the more relevant clinical method based on the reduction in time it allowed. The canals were irrigated using clinical

materials and, of probably equal importance, similar clinically determined irrigation pressures. The canals were dried with sterile paper points according to clinical parameters.

The most effective debridement in both teeth and resin blocks occurred when ultrasonication was used after completion of hand instrumentation. We theorized that ultrasonication loosened debris from the canal walls and thus allowed more complete removal with the subsequent 5-ml irrigation.

Ultrasonication proved to be a useful adjunct to endodontic debridement both in time and efficiency. Assuming a 15-minute canal preparation time clinically, the 30 seconds, or 3.3% of additional time, for ultrasonication produced a 10% increase in debridement of the canal contents. In both the teeth and the resin blocks, ultrasonication reduced by half the residual debris in the root canal space that was left after hand instrumentation. The use of hand instruments, however, is still recommended for enlarging and shaping the canal for obturation. Our results indicate that ultrasonication is a valuable aid to the conventional debridement technique if it is used in the proper sequence with hand instruments.

SUMMARY

Resin blocks containing simulated root canal spaces were compared with extracted teeth as models for measuring the efficiency of endodontic debridement using hand instrumentation, ultrasonication, or a combination of both techniques. Canal spaces were filled with radioisotope-laden gelatin, and the loss of radioactivity was measured after treatment.

No significant differences in efficiency of debridement were observed in teeth prepared with hand instruments or ultrasonics alone; both techniques reduced radioactivity by between 77% to 79%. Ultrasonication after hand instrumentation was the most efficient method; it reduced radioactivity by 88%. Similar results were obtained in the resin blocks except that the ultrasonic debridement alone was not as effective as the hand instrumentation alone.

Ultrasonication is not suggested as an alternative to conventional hand instrumentation, but it is a significant aid in increasing the efficiency of endodontic debridement.

The opinions expressed herein are those of the authors and are not to be construed as those of the Army Medical Department.

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