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METHODS FOR QUANTIFYING SEALING ABILITY OF ENDODONTIC SEALERS-A REVIEW

[1] Sannapureddy Swapna [1] Post graduate
[2]Madhusudhana Koppolu [2] Professor and Head
[3]Suneelkumar Chinni [3] Reader
[4]Anumula Lavanya [4] Reader
[5]Govula Kiranmayi [5] Senior Lecturer

[1-4] Department of Conservative Dentistry and Endodontics, Narayana Dental College, Nellore, Andhra Pradesh, India.

ABSTRACT: The current concept among clinicians is that after complete debridement, a three-dimensional obturation of the root canal space that is free of inflammation constitutes the key factor for successful endodontic therapy. Different sealer formulations have been subjected to extensive research with respect to their mechanical and biological properties, reflecting the prevailing belief that the appropriate selection of a sealer and its clinical performance may influence, at least in part, the outcome of endodontic therapy. Many techniques have been suggested and evaluated, most of them advocating the use of gutta-percha as the core material and with sealer of a different composition to fill the residual gaps between the individual gutta-percha points and between the gutta-percha and the canal wall. Evaluating the sealing competency of the sealers to the root canal walls is utmost consequential for the presage of outcome of treatment.

KEYWORDS: Obturation, Endodontic, Gutta percha, sealer

INTRODUCTION

Preserving teeth and salvaging it from extraction is getting more attention in eyes of researchers in the field of dentistry. Root canal treatment is the only effective, and less invasive and ideal treatment modality for a grossly decayed tooth that cannot be saved by any other conservative procedures. Predictable success of endodontic treatment requires accurate diagnosis, proper cleaning and shaping and hermetically obturation of the root canal.[1] It is essential to maintain the sterile environment of the root canals by providing a perfect seal with the help of root canal sealer and the obturation material.[2]

Definition: These are Cements / Resins / Semi liquid / Plastic -which are used as binding agents to fill up the gap between root canal and obturating material. It also fills up the irregularities, discrepancies, all the space the gutta-percha is unable to fill because of gutta-percha's physical limitations, lateral canals and accessory canals.
It helps to achieve a proper apical seal.[3]

Importance of sealer: The sealer acts as a binding agent, to the dentin and to the core material, which usually is gutta-percha. The sealers are usually a mixture that hardens by chemical reaction, such reaction normally includes the release of toxic material, making the sealer less biocompatible.[4]

Several sealers and cements, such as AH-26, AH-Plus, Ketac-Endo and Diaket may be used as the sole filling material because they have sufficient volume stability to maintain a seal. Under such preventing excess is often difficult because the sealer is applied with a lentilospiral. There are a variety of sealers from among which to choose and the clinician must be careful to evaluate all characteristics of a sealer before selecting.

The concept of apical seal has lead to search for filling and sealing materials that were stable, non-irritating and provided a perfect seal at the apical foramen. At one time it was thought that the sealer played a secondary role by simply cementing (binding or luting) the core filling material into the canal; however it is now appreciated that the sealer has a primary role in sealing the canal by obliterating the irregularities between the canal wall and the core material. All modern filling techniques made use of sealer to enhance the seal of the root canal filling.

Failure: Inflammation and infection continues and bacteria can pass into the periapical tissues if the canal is not completely cleaned and sealed, lack of resolution of periapical lesions and possibly fracture of the roots.[5]

Sealing ability: Three-dimensional sealing of root canals is one of the main goals of endodontic treatment by preventing the re-infection of the canal and for preserving the health of the periapical tissues. Moreover, 60% of endodontic failures can be attributed to incomplete filling of the root canal system.[6] An ideal root canal sealer should have low leaking resistance to promote improved

sealing thus maintaining the bacteria inactive.[7] The sealing ability is a basic feature that needs to be tested for every root canal obturation. But most of the root canal sealers leak to some extent, and most leakage occurs between the root canal walls and the sealer.

At present, leakage studies are widely used in different degrees of subjective analysis and more objective means by spectrophotometry of radioisotopes and electrochemical methods. In addition, volume addition leakage has been measured quantitatively by gas chromatography. Thus, currently, there is no definitive method for the quantitative analysis.

Endodontic obturation techniques and filling materials can be assessed in clinical investigations, but such studies require long observation periods to be meaningful and are, therefore, often difficult to complete due to dropping out of enrolled subjects. Clinical investigations are also difficult to standardize and the results may vary due to differences in the skills of the operators as well as differences in the criteria used for evaluation of the results. Therefore, various in vitro techniques have been introduced to evaluate the sealing ability of different obturation techniques and filling materials to form an adequate apical seal. Most of these methods are based on the assessment of microleakage along the obturated root canal. In recent decades an increasing number of leakage studies have been published.[8-10]

Various methods to detect sealing ability of sealers:

I**. Penetration studies**
- a. Dye penetration
- b. Radio isotopes
- c. Bacterial studies
- d. Bacterial toxins and bacterial products
- e. Neutron activated analysis
- f. Chemical diffusion technique

II. Fluid conduction studies
- a. Fluid transport device

III. Electronic method
- a. Electrochemical studies
- b. Electronic monitoring of microleakage

IV. Microscopic examination
- a. Scanning electron microscope
- b. Fluorescent microscopy
- c. Confocal microscope

V. Miscellaneous
- a. Resin infiltration method

VI. Recent advances
- a. Constant depth form fermentor
- b. Three-dimensional (3D) methods

PENETRATION STUDIES

A] Dye penetration: They are organic tracers used in dentistry to detect microleakage. They may be solutions or particles of suspension. Dye leakage can be evaluated in any of the following ways.

a. Passive
b. Negative Pressure
c. Positive pressure
d. Centrifuge.

A diverse range of dye agents with different concentrations has been introduced into the technique, in which 0.5% Basic Fuchsin, 2% Methylene Blue and 50% silver nitrate solution have been most frequently used.
The methodology has many advantages over the other techniques. The researchers can have a range of choices of available dye agents, highly feasible in any circumstances and can be easily repeated. The method is destructive because the specimen is required to be sectioned so that the staining dye layer is measured and recorded under light microscopy or scanning electron microscopy. This neither allows the method to be reproduced nor is the specimen capable of being long-term assessed. It is highly technique sensitive and is not able to exclude the diffusion of the dye substance into tooth structures and the restoration from the measurement.

B] R**adioactive isotopes:** The use of isotopes was on the inherent ability of isotopes to penetrate more deeply than the dye. Autoradiography technique permitted the detection of minute amounts of tracers that otherwise could not be commonly visualized. The isotopes used are: 45Ca, 14C, 131I, 35S, 22Na, 32P, Rb86 and C14. The roots and crowns of the extracted teeth are painted with varnish except for the surface immediately adjacent to experimental restoration. Then the sealed teeth are immersed in the isotope solution for several hours. The isotope leakage at the tooth/restoration interface is detected by the autoradiography of a sectioned specimen. There are many disadvantages arising from the radioisotope study. Firstly, the method is again destructive of specimens and still qualitative in the analyses of results. Secondly, a two-dimensional autoradiograph image is not representative of the three-dimensional image of microleakage. Thirdly, an isotope such as 45Ca has an affinity with tooth structure or restorative materials, leading to increased measurement errors. In addition, isotopes are able to pass through tooth structure or restoration flaws because of their tiny size, resulting in misinterpretation of leakage. Moreover, because of the complicated procedure of radioisotope leakage recording, the results can be affected by other factors such as isotope selection, source and emulsion distance, exposure length and rinsing. Finally, the technique has potential to produce hazardous radiation.[11]

C] B**acterial studies;** This is more realistic than dye and isotope diffusion method because the size of most dye molecules and isotopes is infinitesimal in comparison with bacteria. The filled teeth are placed in broth culture, the filling materials are removed and dentinal shavings are cultured. We can evaluate both apical and coronal leakage

by this method. Bacteria used are Enterococcus faecalis and Streptococcus.[12]

D] Bacterial toxins and bacterial products: Mostly the soluble bacterial factors, which are released by organisms penetrated more efficiently and rapidly than the bacterial cells. Various materials like lipo polysaccharides and cell wall materials such as dextran have shown to provoke inflammatory relations to dental pulp.

E] Neutron Activation Analysis: This method was introduced by Going et al (1968). This method can be used both in vivo and in-vitro. In this method the teeth are isolated with a latex isolator. The test teeth were exposed to a pulsed neutron flux. Irradiation at 1 megawatt for two minutes provided good counting of gamma ray emission were measured with the scintillation detector and a germanium crystal lined to a gamma ray spectrometer. A graph of counts versus channel numbers is plotted so that data in form of numerical printout could be converted into total counts. The calculated uptake expressed as micrograms of manganese per tooth. The technique basically used non-radioactive manganese (Mn) salt as a chemical marker. The advantage is quantifying the results, the method has many disadvantages. Firstly, the technique is complicated, requiring nuclear engineers and involving radioactive isotopes. Secondly, the path and depth of tracer cannot be identified. [13]

F] **Chemical Diffusion Technique:**Described by Crisp, this method requires preparation of a polyester disc. The specimen is placed in the centre of the circular polythene tube and set in a polyester mounting resin. The junction of the enamel / resin interfaces is sealed by applying coats of varnish or nail polish. The apparatus has a U shaped tube with two arms. 10 ml of de-ionized water is added to the right hand arm and the other arm is filled with $CaCl_2$. At various intervals, 2 ml of liquid is withdrawn from the right hand arm with a pipette. The level in the right hand arm is maintained by addition of 2 ml of de-ionized water counting calcium ions in the withdrawn liquid is liquid is carried out in an inductively coupled plasma (ICP) instrument. Any calcium present is detected and this is indicative of a leakage that has occurred.[14]

FLUID CONDUCTION STUDIES

A] Fluid transport Device: This method was developed by Pashley.[15] The teeth are sectioned and connected to a plastic tube filled with de-ionized water. A standard glass capillary tube is connected to the plastic tube at the outlet of the specimen. Using syringe, the air bubble is adjusted to a suitable position within the capillary. The volume of fluid of transport is measured by observing the movement of the air bubble. The displacement of air bubble is recorded as the fluid transport result (F) which is expressed in ml / day.[16] The fluid filtration method was developed on the principle of an air-pressurization technique. The sealing ability of a restoration is indicated by the resistance to the dentine permeability. A main advantage of the methodology is that it is a non-destructive test, quantitative and qualitative analysis as fluid flow can be measured.[17]

ELECTRONIC METHOD:

A] Electrochemical Studies: It is conductimetric technique developed by Jacobson and Von Fraunhoter in 1975. This study was to evaluate changes in the dimension of the dentinal wall and sealer interphase using an electrochemical cell wall. Because glass has a similar coefficient of thermal expansion to the tooth substance glass tube of 4 mm internal diameter and 15 mm of length was chosen for the study. After inserting the material, 4 mm of the glass tube is immersed in a 1% motion of lactic acid. A lead from the brass electrode is connected to one terminal of cut and this is further connected through a series of resistance to a reference secrete that is formed by a nickel – plated mass rod. The circuit is completed when misplace between the test material and pass is occupied by electrodes when there is a leakage of the solution.[18]

MICROSCOPIC EXAMINATION

A] Scanning Electron Microscopy (SEM): SEM is usually used to measure gap formation and depth of penetration of the sealer into the dentinal tubules. The defects at the submicron level can be observed at required magnification such as x 200 or x 1000. Final evaluation is made in the microphotographs.

B**] Confocal Microscopy :** This is a Laser Scanning microscope, which enables in achieving multiple scanning. The advantage here is that it permits optical sectioning of the specimens thereby eliminating artifacts due to manual sectioning.

C] Fluorescent Microscopy : They use UV radiation on selected dye, which are capable of absorbing these radiations at one wavelength and emitting at a different wavelength.

MISCELLANEOUS

A] Resin infiltration Method: Developed mainly to assess the marginal sealing ability to the root canal wall and the root canal filing material at different levels. The specimens are coated with nail polish to within 2 mm of the end of the apex. The resin is prepared dissolving 1.4 grams of resorcinol in 2 ml of 40% formaldehyde solution and the pH adjusted to 8.2 with aqueous potassium hydroxide immediately before use. The teeth are immersed in resorcinol formaldehyde and are allowed to polymerize completely for 4 days at room temperature. All cross sections are transilluminated and viewed at a magnification of x 25 with stereomicroscope and photographs are taken for image analysis. Dark brown

coloured resin areas at the gap at each level are measured using a personal image analysing system.[19]

RECENT ADVANCES

A] Constant depth film fermentor (CDFF): CDFF is one of the recent method of detecting microleakage. CDFF is basically a system to create as in-vivo situation. This generates a large number of bio films. Prepared samples are placed into the CDFF over which the bio films are generated. At periodic intervals the samples are taken up for analysis. The penetration of bacteria from the bio films can be analysed by SEM and vital staining to estimate the leakage.

B] Three-dimensional (3D) methods: The three-dimensional analysis was pioneered by Youngson (1992) who introduced the technique of producing serial sections using a water-cooled wire saw. Each section was approximately 200µm thick and separated by 280 µm. Computer image analyser was then applied to count the surface areas of dye leakage but the volume of leakage was calculated manually. The methodology is destructive of specimens and the technique is highly cumbersome Manual tracing of the dye leakage is inherently subjective. The methodology was then applied and upgraded by Gale, who developed are constructed model with higher resolution, in which the surface separation was approximately 100-200 µm compared to 280 µm in the previous study. Recently, Iwami introduced an improved method based on the technique of continuous surface reductions similar to the above technique in conjunction with an electrical method. In this study, the sequence of surface reduction was more consistent by 100 µm and image taking was made with a surgical operating microscope. Three dimensional images were also created by computer software. Although there were some improvements due to better control of surface reduction compared to serial sectioning, the methodology was again destructive of specimens. The image resolution in depth direction was still low, no qualitative and quantitative analysis was presented.[20]

CONCLUSION

Root canal sealers along with the solid core play a major role in achieving the hermetic seal by filling the accessory canals, voids, spaces and irregularities. Many studies were conducted which concluded that the sealer was essential for effective obturation. . Various reviews stated that endodontic treatment failures are mainly due to lack of proper seal. Root canal filled with a combination of gutta-percha and sealer achieved more successful seal that either gutta-percha or sealer alone. Many methods are available to assess the sealing ability of sealers which are more accurate and give more precise value.

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Corresponding Author

Dr. **Koppolu Madhusudhana** MDS
Professor and Head
Department of Conservative Dentistry and Endodontics,
Narayana Dental College and Hospital,
Nellore.
Email: drmadhuk15@gmail.com
Phone No: 919391046354