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Solubility of endodontic sealers in three common endodontic solvents

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ABSTRACT

Solubility of Endodontic Sealers in Three Common Endodontic Solvents

Ryan W.L. Burleson, D.D.S.

The purpose of this study was to compare the solubility of four sealers in three common endodontic solvents at time intervals of five minutes, ten minutes, and twenty minutes. Recently, there has been a growing number of resin endodontic sealers with multiple studies looking at leakage and very few investigating their solubility. Three resin sealers (AH Plus, Epiphany, and EndoREZ) and one Grossman's formula sealer (Roth's 801) were tested with three common endodontic solvents (Chloroform, Eucalyptol, Endosolv-R). All sealers were mixed according to the manufactors' specifications and placed into metal rings with openings of a diameter of twenty millimeters and height of two millimeters. Forty five samples of each sealer were allowed to set up for at least forty eight hours at thirty seven degrees Celsius with moisture present. A sample size of five was randomly assigned to one of the three solvents and one of the three time groups. The samples were weighed to the 0.0001 gram before being placed in the solvent. After being in the solvent, the samples were allowed to dry for twenty four hours before taking the final weight. An Excel spreadsheet was used to organize the data

and calculate the differences in weight. The data was analyzed in a Split Plot ANOVA employing the REML method and Tukey's HSD. This was accomplished, by using the Jump software. Significance was determined at $P < 0.05$. The results indicated that multiple factors were significant, including solvent, sealer, and the amount of time. Chloroform was the most effective solvent and was the strongest at the twenty minutes time frame. As for the sealers, AH Plus and Roth's 801 were the most soluble sealers. Eucalyptol was effective only on Roth's 801. The results of this study show that Epiphany and EndoREZ are not appreciably soluble and Endosolv-R was not clinically effective on any of the four sealers.

DEDICATION

To my family, wife, and two children…
I could not have accomplished this without your love and support.
Thank you for allowing me to reach for my dreams!

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Chapter 1: Introduction

Background

Root canal therapy has been a very predictable mean of preserving natural teeth. A root canal is necessary when the dental pulp of the tooth becomes inflamed, infected, and sometimes needed for restorative reasons (eg. post placement). This can happen as a result of dental caries, dental restorative material placement, or trauma to the tooth. Endodontic therapy removes the damaged pulp, with chemical and mechanical instruments. Finally, the canals are filled with a core material and sealer. After effective root canal therapy a final restoration, which could be a crown or dental filling, is placed on the coronal portion of the tooth.

The success rate of initial root canal therapy is high, yet many teeth every year need to be retreated. Endodontic retreatment requires: finding all canals, removal of all previous filling material (both core material and sealer), reinstrumentation of the canal space and filling with new core material and sealer. Clinicians use solvents to soften the previous filling materials. Endodontic solvents need to be safe and effective at dissolving both gutta-percha, the most common core material, and sealer.

Endodontic sealers are designed to seal the gaps between the core materials and help prevent the root canal system from leakage. Currently,

there is a push in the endodontic community to bond to the dentin walls, thus reducing the leakage of sealers. The most important seal comes from the restoration above the root canal filling, because it disallows or allows leakage from the oral cavity. Also, the literature has a fair amount of research on the solubility of gutta-percha in different endodontic solvents, but there are limited studies on the effects of solvent on root canal sealers. All popular filling techniques leave the apical portion and the walls with sealer, leaving it the last material to be removed in retreatment. The first time one views the walls of a canal with a surgical microscope he/she is surprised, to see what remains in the canal, after removing or believing to removed the previous root canal filling.

This study looked at the solubility of different sealers in three solvents, by looking at the weight of sealer before and after being immersed in one of the three solvents. The two most used solvents in dentistry are chloroform and eucalyptol. As the third sealer, we selected Endosolv-R (Septodont) because it is designed for removal of resin sealers. Hopefully, we have better insight on endodontic solvents and which sealers are more easily retreated. Until, we can ensure all canals are located and chemomechanically instrumented correctly we need to keep in mind the type of core materials and sealers being used and tested for further use. Efforts

should continue to find a more universally effective solvent for use in root canal retreatment.

Statement of the Problem

Is there a difference of solubility among the different types of endodontic sealers in three of the most commonly used solvents (chloroform, eucalyptol, and Endosolv R)?

Significance of the Study

Currently, the hot topic with endodontic sealers is their leakage and how well they fill the canal preparation. The endodontic community is looking to completely fill the canal without any leakage, which is currently unachievable. Ideally, one would want to do this assuming all of the canals were located, instrumented mechanically and chemically correctly, and finally the proper restoration placed. But until all of these paradigms are achieved, it is important that these filling materials can be retreatable. With the current use of resin sealers, there have been very little studies that have looked at solubility of these root canal sealers. In certain areas of the country endodontists report from 25% to 80% of their cases being

retreatments. It seems logical to test different endodontic sealers for their solubility in common endodontic solvents. Endodontists need more information regarding sealers and their solubility in endodontic solvents. Even though it is impossible to know what sealer was initially used to treat a case, studies like this could lend insight about which sealers should be used, if a particular solvent is better than another, or if new solvents need to be sought after.

Null Hypothesis

There is no difference between different endodontic sealers when testing for solubility in three different solvents.

Definition of Terms

Root canal system = a space containing the dental pulp within a tooth.

Root canal preparation = a continuous tapered prep after cleaning and shaping of a root canal.

Root canal therapy = is the removal, cleaning, shaping and obturation of the root canal space.

Root canal retreatment = is redoing a previously treated root canal tooth with the goal of a successful case.

Patency = ability of having a clear path from canal orifice through the entire canal and through the apex of the tooth.

Endodontic sealer = material used to fill in the voids the core material cannot fill.

Endodontic solvent = solution used to soften or dissolve root canal filling materials.

Gutta-percha = the most commonly used endodontic core filling material.

Chloroform = most common endodontic solvent used. Formula = $CHCl_3$.

Eucalyptol = the second most common endodontic solvent used. Formula = $C_{10}H_{18}O$.

Endosolv R = newer solvent designed for removing phenolic resin obturating materials. Composition = 33.5% Phenylethylic alcohol; 66.5% Formamida.

Mixing time = the part of the mixing time required in order to obtain satisfactory mix of components.

Setting time = period of time measured from the end of mixing until the sealer has set according to the conditions of the manufacturer.

AH Plus = an epoxy resin sealer produced by Caulk.

Epiphany = a dual cure, hydrophilic resin sealer by Pentron. Is to be used with Resilon. Methacrylate formula.

Resilon = a new synthetic material based on polymers of polyester. Used as a core root canal filling material. Looks and handles like gutta-percha. Manufactured by Pentron.

EndoREZ = a self priming, hydrophilic, dual cure resin sealer produced by Ultradent. Methacrylate formula.

Roth's 801 Elite Grade = a zinc-oxide and eugenol sealer that is a Grossman's formula sealer produced by Roth International.

Assumptions

(1) Sealer sets as it does in prepared root canals. (2) Endodontic solvent dissolves sealer as it does during retreatment. (3) Sealer removal increases the success of root canal retreatment.

Limitations

(1) This in-vitro study mimics what happens in clinical retreatment of endodontic fillings. (2) Ratios of sealer and solvent are clinically relevant.

Delimitations

(1) Only large sizes of sealer were mixed in order to obtain recordable weights. (2) Sealers were allowed to set up for at least forty eight hours. (3) Only four sealers were tested. (4) Only three solvents were tested.

Chapter 2

Review of Literature

Although several studies (Torabinejad *et al* 2005, Hoskinson *et al* 2002, Marquis *et al* 2006) have concluded the success rate of root canal therapy is quite high, endodontic retreatment is a common procedure in endodontics (Weiger *et al* 1998). Root canal retreatment is an increasing element in endodontic practice (Hepworth and Friedman 1997, Koch 1997). A few reasons (Stabnolz *et al* 1994) for retreatment are missed canals, separated instruments, poor coronal or apical seal (Saunders and Saunders 1994), inadequate debridement and/or filling of the root canal space, and inadequate chemical irrigation. Depending on a variety of circumstances, the clinician must decide between surgical or nonsurgical retreatment. Today, the most commonly used endodontic filling material is gutta-percha and a sealer. Endodontic sealer comes in a variety of compositions: calcium hydroxide, zinc oxide and eugenol, silicon-based, glass ionomer, and resin sealers. Resin sealers are the newest composition of sealer. Sealer is used because gutta-percha alone cannot fill the three dimensional root canal system completely (Nguyen 1994, Schafer 2000). Regardless of the method of obturation, sealer is expressed laterally and apically, leaving it as the last

obstacle for a clinician to obtain patency during retreatment. It is a basic requirement of root filling materials, both core and sealer materials, that they can be removed or retreated (Grossman *et al* 1988). Lately, there has been a large number of studies looking at the leakage of resin sealers, but none have addressed their solubility in endodontic solvents.

Retreatment of previous root canal therapy includes locating all canals, removal of all previous root canal filling (both gutta-percha and sealer), chemomechanical cleaning of canals, and filling the root canal system. There are different methods to perform endodontic retreament including thermal, mechanical, chemical, or a combination of the three (Stabholz *et al* 1994). The two most common endodontic solvents are chloroform and eucalyptol, with chloroform being the most popular and extremely effective for gutta-percha removal (Wilcox 1995, Kaplowitz 1990, Wilcox *et al* 1987). Chloroform has been found to be a carcinogen (Barbosa *et al* 1994, Reuber 1979), but deemed safe in the amounts used as a dental solvent (McDonald and Vire 1992, United States Drug Administration 1976). Recently (Edgar *et al* 2006), chloroform has been found to decrease the intracanal levels of cultivatable *E. faecalis*, which is a microorganism thought to be possibly a cause of failing root canal therapy. Eucalyptol is also effective and safe (Hansen 1998, Zakariasen *et al* 1990,

Uemura *et al* 1997, Wourms *et al* 1990). Although solvents for the removal of gutta-percha has been well studied, the solubility of endodontic sealer in solvents has seen very few studies (Whitworth and Boursin 2000).

Solubility refers to the ability for a given substance, the solute, to dissolve in a solvent. It usually is expressed as grams of solute per litre of solvent. In general, solubilities of solids in liquids increase with temperature and those of gases decrease with temperature and increase with pressure (Atkins and De Paula 2001).

In this study the endodontic sealers were the solutes and chloroform, eucalyptol, or Endosolv R were the solvents. This study followed the International Standard #6876 (2001) specifications for testing root-canal sealing materials, although the focus was slightly different. The ISO #6876 was to standardize looking at sealers, to test their solubility, and sets the standard so that sealers will not dissolve in water, salvia, or saline.

CHAPTER III

MATERIALS AND METHODS

SAMPLE DESCRIPTION

Four sealers (Roth's Elite 801, AH Plus, Epiphany, EndoREZ) were all mixed according to the manufactor's specifications. There were 45 test samples of each sealer placed into metal rings with openings of a diameter of twenty millimeters and height of two millimeters. These samples were allowed to set up for at least forty eight hours or more at thirty seven degrees Celsius with moisture present. The samples of Roth's took twenty five days to set up. Prior to creating the samples, the metal rings were cleaned with acetone in an ultrasonic cleaner for twenty minutes. New rings were used for each sealer group being tested. The sample was deemed completely set up when a clean explorer would not penetrate into the test sample. Each sample was assigned a number, which was carved into the metal ring. Also, a hole was placed at the top of the ring to allow for suspension in solvent.

Table 1. Sample Design

	AH Plus	Epiphany	EndoREZ	Roth's801	Control
Eucalyptol 5 mins	5	5	5	5	0
Eucalyptol 10 mins	5	5	5	5	0
Eucalyptol 20 mins	5	5	5	5	4
Chloroform 5 mins	5	5	5	5	0
Chloroform 10 mins	5	5	5	5	0
Chloroform 20 mins	5	5	5	5	4
Endosolv-R 5 mins	5	5	5	5	0
Endosolv-R 10 mins	5	5	5	5	0
Endosolv-R 20 mins	5	5	5	5	4

SOLUBILITY METHODOLOGY

The samples were weighed on a digital scale to 0.0001 of a gram. Each sample was tested in one of the three solvents (Chloroform, Eucalyptol, Endosolv R) for one of three different times (five minutes, ten minutes, or twenty minutes). After being removed from the solvent the samples were rinsed with distilled water and allowed to completely dry for twenty four hours. The samples were weighed again on the same devise.

During both measurements the devise was tared back to zero prior to weighing each sample. One control sample, which was a metal ring with no sealer, was tested for each of the sealer groups in each of the solvents for 20 minutes.

DATA COLLECTION

The results were collected and placed into an Excel spreadsheet. The difference between the before and the after weights of each sample was calculated.

Table 2. Data Table

Column1	Before	After	Difference
EndoRez Sample #1/Euc 5mins	30.7651	30.76	0.0051
EndoRez Sample #2/Euc 5mins	31.8937	31.8894	0.0043
EndoRez Sample #3/Euc 5mins	29.9762	29.9706	0.0056
EndoRez Sample #4/Euc 5mins	33.4353	33.4292	0.0061
EndoRez Sample #5/Euc 5mins	35.0395	35.0342	0.0053
EndoRez Sample #1/Euc 10mins	34.3293	34.3047	0.0246
EndoRez Sample #2/Euc 10mins	30.4457	30.4184	0.0273
EndoRez Sample #3/Euc 10mins	28.9732	28.9511	0.0221
EndoRez Sample #4/Euc 10mins	32.3394	32.3167	0.0227
EndoRez Sample #5/Euc 10mins	31.0738	31.0482	0.0256
EndoRez Sample #1/Euc 20mins	32.9113	32.8769	0.0344
EndoRez Sample #2/Euc 20mins	30.4567	30.4266	0.0301
EndoRez Sample #3/Euc 20mins	29.7208	29.6867	0.0341
EndoRez Sample #4/Euc 20mins	32.6426	32.6016	0.041
EndoRez Sample #5/Euc 20mins	31.7345	31.7011	0.0334
EndoRez Sample #1/Chlor 5mins	31.0426	30.9831	0.0595
EndoRez Sample #2/Chlor 5mins	32.3341	32.2734	0.0607
EndoRez Sample #3/Chlor 5mins	31.0477	30.9876	0.0601
EndoRez Sample #4/Chlor 5mins	27.5321	27.4774	0.0547
EndoRez Sample #5/Chlor 5mins	29.8642	29.8061	0.0581
EndoRez Sample #1/Chlor 10mins	28.7963	28.7402	0.0561

EndoRez Sample #2/Chlor 10mins	34.0143	33.9565	0.0578
EndoRez Sample #3/Chlor 10mins	30.9876	30.9294	0.0582
EndoRez Sample #4/Chlor 10mins	27.3451	27.291	0.0541
EndoRez Sample #5/Chlor 10mins	29.4328	29.3773	0.0555
EndoRez Sample #1/Chlor 20mins	32.4569	32.3578	0.0991
EndoRez Sample #2/Chlor 20mins	29.0419	28.9432	0.0987
EndoRez Sample #3/Chlor 20mins	30.9432	30.8461	0.0971
EndoRez Sample #4/Chlor 20mins	35.6722	35.5729	0.0993
EndoRez Sample #5/Chlor 20mins	32.5238	32.4244	0.0994
EndoRez Sample #1/E-Solv 5mins	29.6167	29.6133	0.0034
EndoRez Sample #2/E-Solv 5mins	28.7757	28.7736	0.0021
EndoRez Sample #3/E-Solv 5mins	29.9634	29.9598	0.0036
EndoRez Sample #4/E-Solv 5mins	33.4511	33.447	0.0041
EndoRez Sample #5/E-Solv 5mins	32.4532	32.4485	0.0047
EndoRez Sample #1/E-Solv 10mins	33.4568	33.4489	0.0079
EndoRez Sample #2/E-Solv 10mins	31.5218	31.5129	0.0089
EndoRez Sample #3/E-Solv 10mins	29.6347	29.6266	0.0081
EndoRez Sample #4/E-Solv 10mins	28.4911	28.4839	0.0072
EndoRez Sample #5/E-Solv 10mins	30.2323	30.2264	0.0059
EndoRez Sample #1/E-Solv 20mins	37.0453	37.0104	0.0349
EndoRez Sample #2/E-Solv 20mins	29.1753	29.1346	0.0407
EndoRez Sample #3/E-Solv 20mins	28.1454	28.1143	0.0311
EndoRez Sample #4/E-Solv 20mins	30.9432	30.9101	0.0331
EndoRez Sample #5/E-Solv 20mins	32.3567	32.324	0.0327
Test Ring Euc	32.0762	32.0762	0
Test Ring Chlor	31.9838	31.9839	-1E-04
Test Ring E-Res	36.2781	36.2782	-1E-04

Epiphany Sample #1/Euc 5mins	32.8657	32.8653	0.0004
Epiphany Sample #2/Euc 5mins	29.7661	29.7658	0.0003
Epiphany Sample #3/Euc 5mins	32.4512	32.4505	0.0007
Epiphany Sample #4/Euc 5mins	30.0853	30.0851	0.0002
Epiphany Sample #5/Euc 5mins	28.4115	28.4113	0.0002
Epiphany Sample #1/Euc 10mins	31.7811	31.7802	0.0009
Epiphany Sample #2/Euc 10mins	32.4356	32.4349	0.0007
Epiphany Sample #3/Euc 10mins	29.8867	29.8856	0.0011
Epiphany Sample #4/Euc 10mins	35.6321	35.6309	0.0012
Epiphany Sample #5/Euc 10mins	30.9432	30.9426	0.0006
Epiphany Sample #1/Euc 20mins	33.4534	33.4526	0.0008
Epiphany Sample #2/Euc 20mins	32.0563	32.0552	0.0011
Epiphany Sample #3/Euc 20mins	29.9579	29.9572	0.0007
Epiphany Sample #4/Euc 20mins	31.4523	31.4518	0.0005
Epiphany Sample #5/Euc 20mins	26.5623	26.5616	0.0007
Epiphany Sample #1/Chlor 5mins	29.4382	29.4117	0.0265
Epiphany Sample #2/Chlor 5mins	30.4532	30.4321	0.0211
Epiphany Sample #3/Chlor 5mins	32.6579	32.6276	0.0303
Epiphany Sample #4/Chlor 5mins	36.0012	35.9733	0.0279
Epiphany Sample #5/Chlor 5mins	28.7221	28.6943	0.0278

Epiphany Sample #1/Chlor 10mins	31.3347	31.2561	0.0786
Epiphany Sample #2/Chlor 10mins	32.8436	32.7603	0.0833
Epiphany Sample #3/Chlor 10mins	29.0443	28.9682	0.0761
Epiphany Sample #4/Chlor 10mins	32.1789	32.1017	0.0772
Epiphany Sample #5/Chlor 10mins	33.1148	33.0355	0.0793
Epiphany Sample #1/Chlor 20mins	34.3217	34.2423	0.0794
Epiphany Sample #2/Chlor 20mins	30.6473	30.58	0.0673
Epiphany Sample #3/Chlor 20mins	27.6653	27.5879	0.0774
Epiphany Sample #4/Chlor 20mins	29.6547	29.5656	0.0891
Epiphany Sample #5/Chlor 20mins	31.5732	31.4849	0.0883
Epiphany Sample #1/E-Solv 5mins	33.7686	33.7475	0.0211
Epiphany Sample #2/E-Solv 5mins	29.1445	29.1211	0.0234
Epiphany Sample #3/E-Solv 5mins	30.1045	30.0836	0.0209
Epiphany Sample #4/E-Solv 5mins	36.4126	36.3927	0.0199
Epiphany Sample #5/E-Solv 5mins	34.3223	34.3006	0.0217
Epiphany Sample #1/E-Solv 10mins	31.4359	31.4131	0.0228
Epiphany Sample #2/E-Solv 10mins	33.4397	33.4156	0.0241
Epiphany Sample #3/E-Solv 10mins	27.6113	27.5882	0.0231
Epiphany Sample #4/E-Solv 10mins	30.4571	30.437	0.0201
Epiphany Sample #5/E-Solv 10mins	28.6732	28.6511	0.0221
Epiphany Sample #1/E-Solv 20mins	29.8217	29.798	0.0237
Epiphany Sample #2/E-Solv 20mins	36.5117	36.4886	0.0231
Epiphany Sample #3/E-Solv 20mins	30.7327	30.7126	0.0201
Epiphany Sample #4/E-Solv 20mins	28.7641	28.7398	0.0243
Epiphany Sample #5/E-Solv 20mins	33.4894	33.4638	0.0256
Test Ring Euc	32.0763	32.0762	0.0001
Test Ring Chlor	31.9838	31.9838	0
Test Ring E-Res	36.2782	36.2783	-0.0001

AH Plus Sample #1/Euc 5mins	29.6403	29.6347	0.0056
AH Plus Sample #2/Euc 5mins	33.3673	33.3621	0.0052
AH Plus Sample #3/Euc 5mins	35.0353	35.0306	0.0047
AH Plus Sample #4/Euc 5mins	33.297	33.2907	0.0063
AH Plus Sample #5/Euc 5mins	36.0991	36.092	0.0071
AH Plus Sample #1/Euc 10mins	30.451	30.4431	0.0079
AH Plus Sample #2/Euc 10mins	30.9722	30.9639	0.0083
AH Plus Sample #3/Euc 10mins	34.9017	34.8926	0.0091
AH Plus Sample #4/Euc 10mins	36.9233	36.9162	0.0071
AH Plus Sample #5/Euc 10mins	23.4756	23.4679	0.0077
AH Plus Sample #1/Euc 20mins	31.917	31.8819	0.0351
AH Plus Sample #2/Euc 20mins	29.6301	29.6004	0.0297
AH Plus Sample #3/Euc 20mins	35.9459	35.9127	0.0332
AH Plus Sample #4/Euc 20mins	34.7695	34.7312	0.0383
AH Plus Sample #5/Euc 20mins	34.8782	34.8411	0.0371
AH Plus Sample #1/Chlor 5mins	30.9505	30.5906	0.3599
AH Plus Sample #2/Chlor 5mins	30.6808	30.2686	0.4122
AH Plus Sample #3/Chlor 5mins	30.3987	30.0224	0.3763
AH Plus Sample #4/Chlor 5mins	30.377	29.9828	0.3942

AH Plus Sample #5/Chlor 5mins	32.2863	31.9396	0.3467
AH Plus Sample #1/Chlor 10mins	29.4834	28.8585	0.6249
AH Plus Sample #2/Chlor 10mins	31.383	30.7092	0.6738
AH Plus Sample #3/Chlor 10mins	36.6017	35.9631	0.6386
AH Plus Sample #4/Chlor 10mins	32.5594	31.9253	0.6341
AH Plus Sample #5/Chlor 10mins	29.7727	29.1608	0.6119
AH Plus Sample #1/Chlor 20mins	30.6044	29.3836	1.2208
AH Plus Sample #2/Chlor 20mins	33.4172	31.9844	1.4328
AH Plus Sample #3/Chlor 20mins	34.9437	33.724	1.2197
AH Plus Sample #4/Chlor 20mins	30.3995	29.2879	1.1116
AH Plus Sample #5/Chlor 20mins	31.8261	30.7329	1.0932
AH Plus Sample #1/E-Solv 5mins	34.5871	34.5862	0.0009
AH Plus Sample #2/E-Solv 5mins	30.3583	30.357	0.0013
AH Plus Sample #3/E-Solv 5mins	29.6166	29.6159	0.0007
AH Plus Sample #4/E-Solv 5mins	34.685	34.6837	0.0013
AH Plus Sample #5/E-Solv 5mins	30.2384	30.2373	0.0011
AH Plus Sample #1/E-Solv 10mins	29.7536	29.7528	0.0008
AH Plus Sample #2/E-Solv 10mins	29.9512	29.9508	0.0004
AH Plus Sample #3/E-Solv 10mins	27.2891	27.288	0.0011
AH Plus Sample #4/E-Solv 10mins	35.3411	35.3403	0.0008
AH Plus Sample #5/E-Solv 10mins	32.3527	32.352	0.0007
AH Plus Sample #1/E-Solv 20mins	27.4867	27.4839	0.0028
AH Plus Sample #2/E-Solv 20mins	35.6864	35.6847	0.0017
AH Plus Sample #3/E-Solv 20mins	35.7368	35.7359	0.0009
AH Plus Sample #4/E-Solv 20mins	32.7565	32.7531	0.0034
AH Plus Sample #5/E-Solv 20mins	34.0519	34.0493	0.0026
Test Ring Euc	32.0762	32.0762	0
Test Ring Chlor	31.9838	31.9839	-1E-04
Test Ring E-Res	36.2783	36.2782	0.0001
Roth's Sample #1/ Euc 5mins	31.8717	31.6498	0.2219
Roth's Sample #2/ Euc 5mins	32.4731	32.1938	0.2793
Roth's Sample #3/ Euc 5mins	30.291	30.1001	0.1909
Roth's Sample #4/ Euc 5mins	29.3689	29.1681	0.2008
Roth's Sample #5/ Euc 5mins	33.7641	33.5468	0.2173
Roth's Sample #1/ Euc 10mins	31.8269	31.6364	0.1905
Roth's Sample #2/ Euc 10mins	30.6425	30.4251	0.2174
Roth's Sample #3/ Euc 10mins	28.9939	28.7464	0.2475
Roth's Sample #4/ Euc 10mins	32.3471	32.1608	0.1863
Roth's Sample #5/ Euc 10mins	34.0728	33.8152	0.2576
Roth's Sample #1/ Euc 20mins	32.0614	31.843	0.2184
Roth's Sample #2/ Euc 20mins	33.6841	33.3947	0.2894
Roth's Sample #3/ Euc 20mins	30.9438	30.7452	0.1986
Roth's Sample #4/ Euc 20mins	31.7892	31.5327	0.2565
Roth's Sample #5/ Euc 20mins	32.4563	32.2199	0.2364
Roth's Sample #1/ Chlor 5mins	37.6086	37.2532	0.3554
Roth's Sample #2/ Chlor 5mins	35.7182	35.4008	0.3174
Roth's Sample #3/ Chlor 5mins	34.7683	34.3721	0.3962

Roth's Sample #4/ Chlor 5mins	29.0384	28.6642	0.3742
Roth's Sample #5/ Chlor 5mins	30.4117	30.0456	0.3661
Roth's Sample #1/ Chlor 10mins	37.3149	36.8998	0.4151
Roth's Sample #2/ Chlor 10mins	34.4762	34.0915	0.3847
Roth's Sample #3/ Chlor 10mins	32.5379	32.0707	0.4672
Roth's Sample #4/ Chlor 10mins	35.4118	34.9645	0.4473
Roth's Sample #5/ Chlor 10mins	29.9982	29.5615	0.4367
Roth's Sample #1/ Chor 20mins	35.741	34.6784	1.0626
Roth's Sample #2/ Chlor 20mins	33.1026	32.0847	1.0179
Roth's Sample #3/ Chlor 20mins	32.8432	31.5143	1.3289
Roth's Sample #4/ Chlor 20mins	29.0973	27.9249	1.1724
Roth's Sample #5/ Chor 20mins	34.3546	33.3577	0.9969
Roth's Sample #1/ E-Solv 5mins	36.5189	36.4757	0.0432
Roth's Sample #2/ E-Solv 5mins	31.7653	31.7207	0.0446
Roth's Sample #3/ E-Solv 5mins	29.7891	29.738	0.0511
Roth's Sample #4/ E-Solv 5mins	34.5724	34.5346	0.0378
Roth's Sample #5/ E-Solv 5mins	32.4867	32.4475	0.0392
Roth's Sample #1/ E-Solv 10mins	34.8801	34.8246	0.0555
Roth's Sample #2/ E-Solv 10mins	32.5726	32.5189	0.0537
Roth's Sample #3/ E-Solv 10mins	30.8917	30.8336	0.0581
Roth's Sample #4/ E-Solv 10mins	33.8671	33.8104	0.0567
Roth's Sample #5/ E-Solv 10mins	35.1478	35.0966	0.0512
Roth's Sample #1/ E-Solv 20mins	34.5016	34.4519	0.0497
Roth's Sample #2/ E-Solv 20mins	29.6437	29.592	0.0517
Roth's Sample #3/ E-Solv 20mins	32.3282	32.2806	0.0476
Roth's Sample #4/ E-Solv 20mins	31.7664	31.7181	0.0483
Roth's Sample #5/ E-Solv 20mins	34.6789	34.6269	0.052
Test Ring Euc	32.0763	32.0764	-1E-04
Test Ring Chlor	31.9837	31.9836	1E-04
Test Ring E-Res	36.2782	36.2781	1E-04

DATA ANALYSIS

The data was analyzed in a Split Plot Model with the REML (Restricted or Residual Maximum Likelihood Method) and Tukey's HSD anaylsis. This was accomplished, by using the Jump software, with the help of a statistician. Significance was determined at $P < 0.05$. A one-way ANOVA was also used to determine if a significant difference existed

between groups and Tukey's HSD test used to identify which groups were significantly different. Significance was determine at $P < 0.05$. The Tukey analysis was also used to determine statistical differences between by sealers, solvents, and times.

MATERIALS AND EQUIPMENT

- Endosolv R (Septodont, Cedex France)
- Chloroform (Sultan Healthcare Inc., Englewood NJ)
- Eucalyptol (Sultan Healthcare Inc., Englewood NJ)
- 5/8 Flat Washers (Hillman Group Inc., Cincinnati OH)
- EndoREZ (Ultradent, South Jordan UT)
- AH Plus (Dentsply Maillefer, Tulsa OK)
- Epiphany (Pentron Clinical, Wallinford CT)
- Roth's Elite Grade 801 (Roth International, Chicago IL)

CHAPTER IV

RESULTS AND DISCUSSION

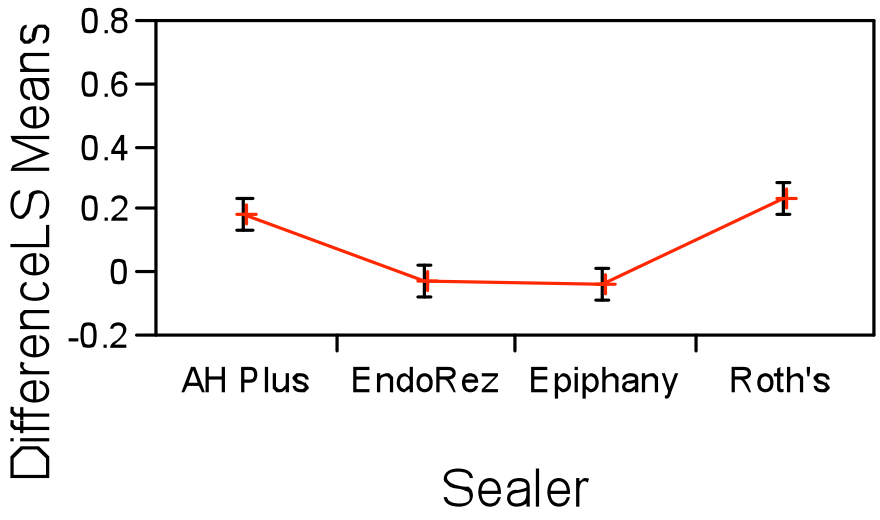
RESULTS

The statistical analysis of the data was performed by a Split Plot Model within the REML method and a Tukey's HSD anaylsis. The results of this study did not support the null hypothesis, that there is no difference between four different endodontic sealers when testing for solubility in three different solvents. The results show the following factors are significant. Solubility depends on the sealer, solvent, and time. Solubility of the sealer depends on which solvent was used. Solubility depends on the effects of the solvent and time.

Solubility of Sealer (p = 0.0028)

AH Plus and Roth's are approximately twice as soluble than Epiphany and EndoREZ. Epiphany and EndoREZ were not soluble in any of the three solvents tested for.

Figure 1. Solubility of Sealers



The sealers AH Plus and Roth's 801 were statistically significant compared to Epiphany and EndoREZ in the Tukey analysis.

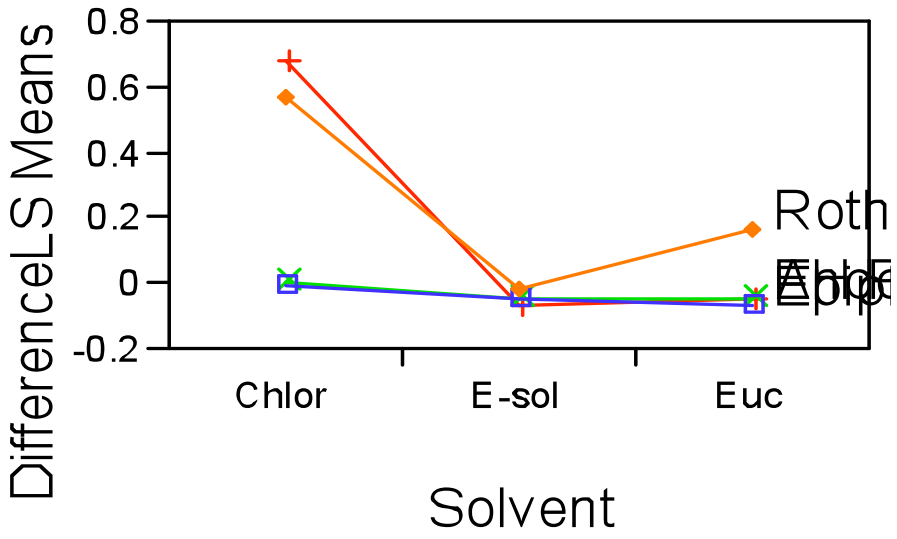
Table 3. Oneway Analysis of Difference By Sealer

Level			Mean
Roth's	A		0.30418222
AH Plus	A		0.25363556
EndoRez		B	0.03596667
Epiphany		B	0.02834889

Solubility of Sealer in Different Solvents

AH Plus and Roth's were 6-7 times more soluble in chloroform than any other combination of sealer-solvent interaction. Also, Roth's was two times more soluble in Eucalyptol than Epiphany or EndoREZ was in any of the three tested solvents.

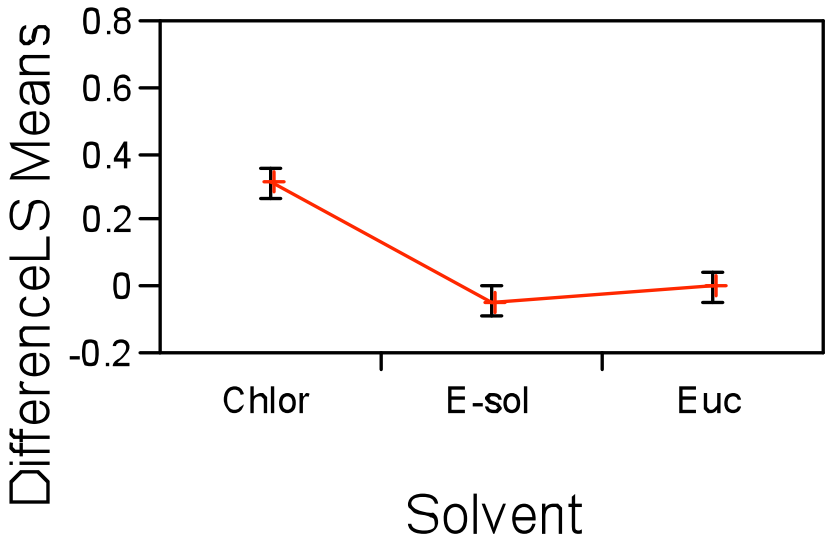
Fig 2. Solubility of Sealer in Different Solvents



Solvents Ability to Dissolve Endodontic Sealer ($p < 0.0001$)

Chloroform was three times more powerful at dissolving the four endodontic sealers tested than the other two solvents, Eucalyptol and Endosolv-R. Although not significant, Eucalyptol was more effective than Endosolv-R.

Fig 3. Solvent Ability to Dissolve Endodontic Sealer



When the Tukey anaylsis evaluated the solvents, chloroform was statistically more effective than eucalyptol and Endosolv-R.

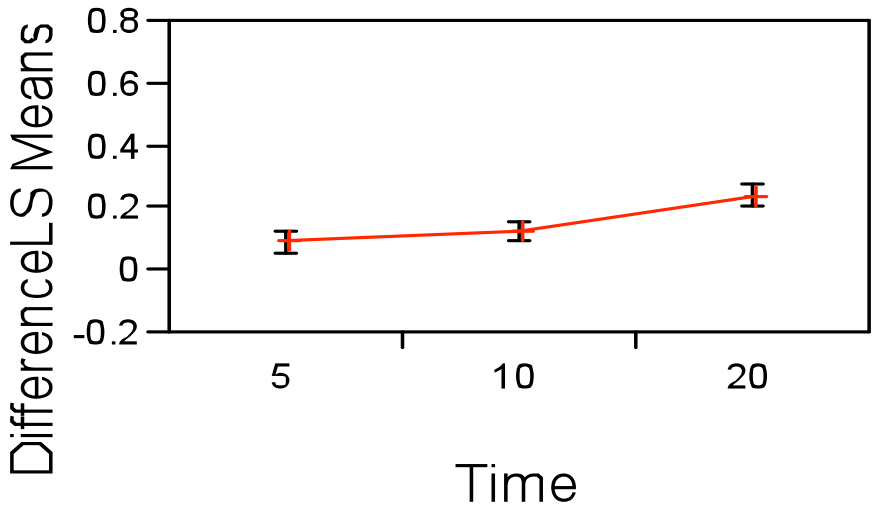
Table 4. Oneway Analysis of Difference By Solvent

Level			Mean
Chlor	A		0.37812833
Euc		B	0.06638333
E-sol		B	0.02208833

Solubility and Time

As the solvent was allowed to interact with the sealer, the longer the time frame the more soluble the sealers became. This was a fairly steady linear relationship.

Fig 4. Solubility and Time



Allowing the solvent a longer time frame was significant. Twenty minutes was statistically more effective than five minutes, according to the Tukey analysis.

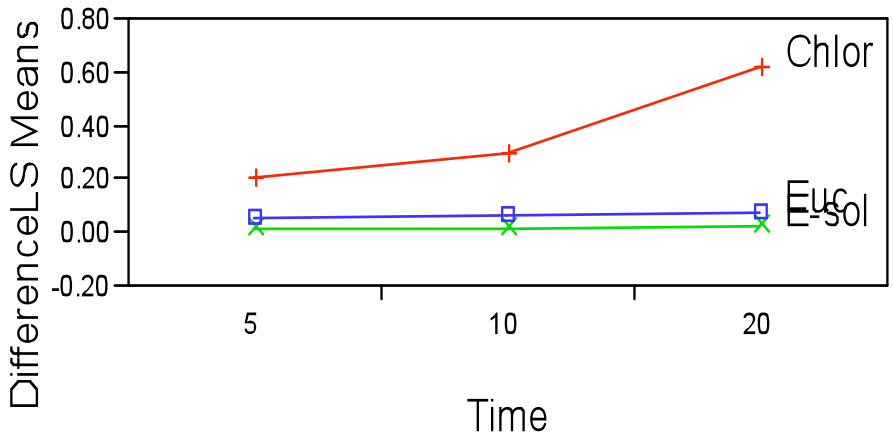
Table 5. Oneway Analysis of Difference By Time

Level			Mean
20	A		0.24419000
10	A	B	0.12843167
5		B	0.09397833

Time and Solvent Interaction ($p < 0.0001$)

Time and solvent interaction was significant, but it was one particular solvent (Chloroform) that caused this statistical significance. Chloroform was six times stronger than Eucalyptol and EndoSolv-R at the 20 minute time interval.

Fig 5. Time and Solvent Interaction



DISCUSSION

As dentistry and the population continue to grow, people will continue to seek better dental health care. The dental profession needs to have clinical research behind the products on the market. According to the results of this study, it indicates the need for more testing of new sealers and their solubility. Chloroform was capable of completely dissolving gutta-percha (Kaplowitz 1991) but did not test for any sealers. This study agrees with previously cited studies that chloroform is the most effective endodontic solvent. It has the capability of dissolving gutta-percha and some sealers, but two of the sealers tested in this study were not soluble in any of the three solvents. Chloroform is not ideal, because of it's poor biocompatibility (USFDA 1976) and decrease in dentin bonding strength (Erdemir et al 2004).

It is reasonable to understand the less leakage a sealer can provide the better, but what if it's not soluble? How can we as clinicians determine which solvent to use when we are blind to what sealer was initially used? These are questions that need to be addressed in the future with sound research, so that the success of retreatment does not decline. The current research on sealer solubility is very limited and is nonexistent for resin

sealers. Hopefully, this current research begins to answer a few of our questions and stimulates more research in this topic.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

The results of this study are multifaceted, because they point out the following observations. First, chloroform, especially used for twenty minutes, is the most effective solvent. Chloroform has been proven to completely dissolve gutta-percha and was the strongest against the four sealers in this experiment. AH Plus and Roth's 801 were much more soluble than EndoREZ and Epiphany, when tested against chloroform, eucalyptol, and Endosolv-R. EndoREZ and Epiphany were not soluble in any of the three solvents used in this study. Our recommendation is for future testing to find a suitable solvent for each of these sealers. Lastly, Endosolv-R was not effective at dissolving any of the four sealers in this experiment. Although it was designed to be used for removal of resorcinol-formaldehyde resin or "Russian Red" type sealers, some have a misunderstanding that it's for all resin sealers. Endosolv-R was not effective on any of the three resin sealers tested for. Although the results of this study do not include all resin sealers, it strongly suggests the need for resin sealers on the market to have their solubility tested.

CONCLUSIONS

This study suggests the usage of chloroform as an endodontic solvent and the longer it is allowed to dissolve gutta-percha and sealer the softer those materials become. According to our data, Epiphany and EndoREZ should not be used unless an acceptable solvent can be found for them. Lastly, Endosolv-R should only be used on resorcinol-formaldehyde resin, which is easily identifiable due to it's distinct color, and should not be used on the new resin sealers.

References

Atkins PW, De Paula J. Atkin's Physical Chemistry. 7th Edition. New York, W.H. Freeman & Co.: 2001. pg 163-189.

Barbosa SV, Burkard DH, Spangberg LS. Cyctotoxic effects of gutta-percha solvents. *J Endodon* 1994; 20: 6.

Edgar SW, Marshall JG, Baumgartner JC: The antimicrobial effect of chloroform of Enterococcus faecalis after gutta-percha removal. *J Endodon* 2006; 32(12): 1185-7.

Erdemir A, Eldeniz AU, Belli S, Pashley DH. Effects of Solvents of Bonding to Root Canal Dentin. *J Endodon* 2004; 30(8): 589-92.

Grossman LLI, Oliet S, del Rio CE. Endodontics. 11 th ed. Philadelphia, PA: Lea and Febiger: 1998. pg 242-70.

Hansen MG. Relative efficiency of solvents used in endodontics. *J Endodon* 1998; 24: 38-40.

Hepworth MJ, Friedman S. Treatment outcome of surgical and non-surgical management of endodontic failures. *J Canad Dent Assoc* 1997; 63: 364-71.

Hoskinson SE, Ng YL, Hoskinson AE, Moles DR, Gulabivala K. A retrospective comparasion of outcome of root canal treatment using two different protocols. *Oral Surg Oral Med Oral Patholo* 2002; 93(6): 705-15.

International Organization for Standardization. International Standard ISO 6876: dental root canal sealing materials. 2001.

Kaplowitz, GJ. Evaluation of the Ability of Essential Oils to Dissolve Gutta-Percha. *J Endodon* 1991; 17(9): 448-9.

Koch H. The microscope: It's effect on your practice. *Dent Clin N America* 1997; 41: 619-26.

Marquis VL, Dao T, Farzaneh M, Abitbol S, Friedman S. Treatment Outcomes in Endodontics: The Toronto Study. Phase III: Initial Treatment. *J Endodon* 2006; 32(4): 299-306.

McDonald MN and Vire DE. Chloroform in the Endodontic operatory. *J Endodon* 1992;18: 301.

Nguyen TN. Obturation of the root canal system. In: Cohen S, Burns RC, editors. Pathways of the pulp. 6 th ed. St. Louis: Mosby; 1994; pg 219-71.

Reuber MD. Carcinogenicity of chloroform. *Environ Health Persect* 1979; 31: 171-82.

Saunders WP, Saunders EM. Coronal leakage as a cause of failure in root canal therapy: a review. *Endod Dent Traumatol* 1994; 10: 105-8.

Schafer E. Root filling materials. *Dtsch Zahnarztl Z* 2000; 55: 15-25.

Stabholz A, Friedman S, Tames A. Endodontic failures and retreatment. In: Cohen S, Burns RC, editors. Pathways of the pulp. 6 th ed. St. Louis: Mosby; 1994. pg 690-728.

Torabinejad M, Kutesenko D, Machnick TK, Ismail A, Newtoan CW. Levels of Evidence for the Outcome of Nonsurgical Endodontic Treatment. *J Endodon* 2005; 31(9): 637-46.

Uemura M, Hata G, Toda T, Weine FS. Effectiveness of Eucalyptol and *d*-Limonene as gutta-percha solvents. *J Endodon* 1997; 23: 739-41.

United States Drug Administration. Chloroform Used as an Ingredient (active or inactive) in Drug Products. *U.S. Government Printing Office* 1976; Washington, DC.

Weiger R, Axmann-Kremar D, Lost C: Prognosis of conventional root canal treatment reconsidered. *Endodo Dent Traumatol* 1998; 14: 1-9.

Whitworth JM, Boursin EM. Dissolution of root canal sealer cements in volatile solvents. *Int Endod J* 2000; 33: 19-24.

Wilcox LR. Endodontic retreatment: ultrasonics and chloroform solvent. *J Endodon* 1995; 13: 453-7.

Wilcox LR, Krell DV, Madison S, Rittman B. Endodontic retreatment: evaluation of gutta-percha and sealer removal and canal reinstrumentation. *J Endodon* 1987; 13: 435.

Wourms DJ, Campbell AD, Hicks ML, Pelleu GB. Alternative solvents to chloroform for gutta-percha removal. *J Endodon* 1990; 16: 224-6.

Zakariasen KL, Brayton SM, Collinson DM. Efficient and effective root canal retreatment without chloroform. *J Can Dent Assoc* 1990; 56: 509.

CURRICULUM VITAE

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Objective

After obtaining my D.D.S. from West Virginia University School of Dentistry in 2002, I began to practice general dentistry with my father. I am currently enrolled in the Endodontic residency at WVU and will finish the program in 2008.

Summary

I am currently establishing a private practice limited to endodontics in the city of Apex, NC.

Education

Miami University, Oxford, Ohio 1995-1998
West Virginia University, Morgantown, WV 1998-2002
West Virginia University, Endodontic Residency, 2006-2008

Experience

Burleson Dental Practice, LLC; 2002-present
Dentist, Partner

- Participant of the State of Ohio Scioto County Sealant Public Health Program.
- Associate of the Ohio Department of Health's Bureau for Children with Medical Handicaps.

WVU Department of Endodontics; 2006- present
Endodontic Resident

- Will obtain a M.S. from an Accredited Program of Endodontics

Linda and Bill Ray, DDS, PLLC; 2007-present
Dentist, Associate

- Performed endodontic therapy and managed staff.

References

Available upon request.