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Applying TRIZ to Endodontic Tool Design

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Executive Summary

Endodontics, commonly known to non-dentists as "root canals" is a complex system where the art and science of dentistry meet the art and science of tool design. The dentist opens the tooth, removes diseased tissue from the pulp chamber, treats the infection in the tissue surrounding the tooth, and re-seals the tooth. All the diseased tissue must be removed to prevent future infection, but the minimum amount of tooth structure must be removed to preserve the strength and function of the tooth. These activities are done inside the tooth, in a twisted channel with varying diameter, in the human environment of blood, pus, bacteria and saliva. The dentist must perform the operation in these constrained circumstances while maintaining pain control for the patient and in such a way as to permit final restoration of the tooth. See Figures 2 and 3. /Lit1/ Lit2/

Dr. Jack Jacklich is the developer of a wide range of techniques and tools used to improve the precision and speed with which the dentist can operate on a tooth. Prior to his TRIZ training, many of Dr. Jacklich's designs showed several characteristics of intuitive TRIZ designs. Since starting TRIZ training, the TRIZ characteristics have become much more prominent, and the use of the "itself" approach to ideality has become a featured characteristic of his designs.

The case study will show three of Dr. Jacklich's tool systems, and demonstrate the use of TRIZ to improve ideality, use existing resources, and to remove both tradeoff and inherent (technical and physical) contradictions and to improve designs. In addition, the instructor's perspective on how a beginner applies TRIZ, and the value of beginner TRIZ training, (as opposed to complete, advanced TRIZ training) will be explored.

Introduction

Tool design is one of the obvious areas for the use of TRIZ, since the designer is frequently faced with situations that are expressed as tradeoffs or as impossibilities. When the tool designer also is the operator of a small business, and must include the requirements to manufacture, distribute, and support the product at a profit as well as the design requirements, the opportunities to use both business applications of TRIZ and Technical applications of TRIZ multiply. /Lit3/

This case study was not begun to prove anything about TRIZ. This case study had its origin in the work of Dr. Jack Jacklich, founder of Special Products, Inc.,/Lit1/ and designer of an extensive family of techniques and tools for endodontics. Frequently, Dr. Jacklich developed a technique that he could use,

but that was difficult to teach to others, so he would develop a special tool to make it easy for them to use his technique. For a summary of the history of the technique and product families, see figure 4. Special Products, Inc. was formed to market Dr. Jacklich's tools, and Continuing Education Centers of America was formed to teach his techniques, which are now taught internationally through on-line courses and presentations at international conferences.

Dr. Jacklich's intuitive use of TRIZ was manifest in the first technique development in 1972. In his own words

My epiphany occurred one Sunday in July 1972 while waiting for the Super Bowl on TV (this was before cable). I whiled away the time watching a documentary on oil well drilling. I watched them using drilling mud (which by the way is barium sulfate) to pump down into the well which flushed out the debris created by the drill bit.

The next day as I was filing with the Giromatic I asked the dental assistant to direct a stream of water into the access cavity while I was cutting.

IT WAS LIKE PUTTING THE GIRO INTO OVERDRIVE!! and I discovered "washed field endo technique." Since the file was on the end of a handpiece (as opposed to on the end of my fingers) it was actually feasible now. Combining Girofiles, Giromatic, Circumferential filing, Washed Field and Syringe Endo made it possible for me to keep up and I've never looked back.

We then began scheduling two endo cases, one for preparation and one for filling in each 45 minute segment of time. (Traditional endodontic procedures took 3-4 hours per tooth.) Needless to say, the owners of the practice were interested in my productivity. And they invited their friends to watch. So...I figured if they were interested, so would a few other people. /Lit1/

Patients are very time-driven, as are the dentists. If an endodontic procedure can be done in 45 minutes, the patient is much more likely to agree to it, than if it takes 4 hours. If anesthesia lasts 2-3 hours, and the patient in a conventional procedure starts to feel pain when the procedure is not yet complete, the bad reputation of endodontia is enhanced. If the entire procedure takes less than an hour, this problem is avoided.

Dr. Jacklich's willingness to use technology from another field, frequently called the use of scientific effects in TRIZ, demonstrates his orientation toward TRIZ-like thinking. In these case studies, we will show a combination of his new developments, after TRIZ training, and his inventions before he learned about TRIZ. See figure 4.

For tool designers who work in laboratory or shop environments, the challenges of working inside the human mouth are extreme. See Figure 3. Performing endodontia (from the Greek, "endo"—inside, "odont"—tooth) requires working blind inside canals that are non-circular in cross section, tapering at a non-constant rate, sometimes branching, and full of infectious material which should not be forced through the canal into healthy tissue. X-rays are used periodically during the procedure to evaluate the progress of cleaning the canals, but the number of x-rays should be limited for the patient's safety and the speed of the operation. There are also electronic instruments that sense the approach of the cutting tool to the apex (tip of the root) by changes in resistance.

TRIZ training.

In 1997 Dr. Jacklich took Ellen Domb's TRIZ training class "Practical Innovation: A TRIZ Learning Event" which is described in /Lit 4/. The basic structure of the beginner problem solving method is shown in Figure 5, and is a conventional presentation of TRIZ for problem solving. One aspect of the teaching methodology, which fits well with Dr. Jacklich's intuitive use of TRIZ, is that students identify their own past use of each of the tools or methods of TRIZ, in order to be able to use them in the future with greater precision. /Lit4/Lit5/

In the 6 years since taking the class, Dr. Jacklich has had no other TRIZ training, and has had only occasional discussions with the instructor, which were not "training"—they were more in the nature of showing the latest developments in his system of endodontics, and in the manufacturing and business systems that make them available to his growing user community. Nevertheless, with no additional training, he is teaching TRIZ to his employees and using the following techniques on a regular basis:

- Ideal Final Result (with the use of resources)
- Resolution of Technical (Tradeoff) Contradictions using the 40 principles
- Resolution of Physical (Inherent) Contradictions using the separation principles
- Using Scientific Effects (alternative technologies)

In addition, in solving the business problems of operating a global business with very few employees, he and his marketing manager and machinist (See figure 15) frequently use

- System Operator (9 Windows)
- Functional Analysis (informally)
- Analysis of Resources

Case Studies

The Periodontal Intraligamentary Syringe (PDL) is shown in figure 7. The negative public image of endodontia is in part due to the pain that patients have endured in the past prior to endodontic procedures. Referring to figure 2, it is obvious that the infection in the root and the abscess in the root/bone interface can block the path to the nerves for anesthetic fluids. The PDL is designed to overcome that problem by injecting anesthetic directly into the periodontal ligament, shown in figure 2. Because this is a very small space between the (incompressible) tooth and bone, high pressure must be used to inject the fluid. At the same time, the dentist must maintain the position of the syringe to avoid damaging tissue, which is usually done by resting the fourth finger of the hand holding the syringe on the patient's jaw. Since the dentist usually uses the other hand to position the patient, only the hand holding the syringe is available to operate the syringe. Dr. Jacklich's design uses a double lever action to amplify the pressure that the dentist can apply with one hand. See figures 7 and 8.

The original PDL was designed in 1982, without benefit of TRIZ. Since 1997, with the use of TRIZ, the number of parts has been reduced by half, the manufacturing process simplified

dramatically, and the ease of sterilization and cleaning (very important to the dentist and dental assisting staff) simplified. Two examples of TRIZ contributions (particularly the use of resources to enhance ideality) to the improvement of the PDL are shown in figure 7

- The use of an extended screw to attach the spring to the pawl and also serve to limit the compression of the handle (replacing a complex, not entirely satisfactory structure to perform the limiting function)
- The use of two opposing custom designed screws to create the pivot for the handle. This simplified the manufacturing process, reduced the parts count, and improved the sterilization of the PDL. The screws are designed to bind, instead of stop, when the heads hit. The screw head is a cylinder with a phillips head on the end. The non-standard head was required to keep the edge of the screw from catching and tearing the dentists' protective gloves.

The Fine-Cut Endo Cartridge Syringe (figure 9) shows other examples of TRIZ applications. This syringe is used, with different cartridges and different needles, for both anesthesia and for filling the canal with specially formulated, bio-compatible cement to prevent new infection after the original infection is removed. After several generations of improvement of the dispensing mechanism, Dr. Jacklich analyzed the functional needs of the user, dispensing very small, precisely regulated quantities, and, considering the constraint of using the cylindrical geometry of the syringe, translated that to the need for very small regulated linear changes. The solution, a form of “using effects” was sitting on his machinists' workbench—a depth measurement micrometer. The combined instrument is shown in the last frame of figure 9.

A new improvement was created while this article was being written, “trimming” the threaded barrel, and replacing it with a disposable, pre-threaded cartridge, eliminating another cleaning problem and making the entire system more attractive to the customer. When asked if this was an application of principle 27, use cheap disposable objects, Dr. Jacklich replied

“I have always called this the Gillette principle—sell them one razor, and they'll come back and buy lots of blades. This makes it faster for assembly, faster for disassembly, and simpler for sterilization, all of which will make the customer come back to us. What TRIZ made me do was look at every part and ask, ‘What is the function? What else could do that function simpler?’ I really didn't think about the specific problem solving principles in this case, but I've definitely become much more conscious of analyzing the functions, and trimming anything unnecessary.”

Circumferential Filing is shown in figure 10. This is another early Jacklich invention, which has been refined, improved, and made commercially successful through the combination of several devices developed with the aid of TRIZ.

Conventional filing with conventional tools, both hand operated and mechanically driven (see figure 10, bottom frame) requires frequent changes of files, starting with small diameters and progressing to larger diameters, to clean the entire length of the canal. Using the circumferential filing technique reduced the number of files from (typically) 8 to 2, with a consequent improvement in the dentist's operating productivity and the patient's comfort.

In TRIZ terms, this is a classical tradeoff situation, with at least 9 pairs of parameter contradictions from the classical Altshuller contradiction matrix, which are also used on the new “Matrix 2003.” /Lit 6/Lit7/

- Volume vs. ease of operation or time or productivity
- Quantity of material vs. ease of operation or time or productivity
- Manufacturing (in this case Production) precision vs. ease of operation or time or productivity

The solution is also a classical TRIZ application, combining principles 14 (spheriodality, or the use of curves) and 17 (use another dimension, combining longitudinal motion with the rotary motion), and the pattern of evolution of increasing automation. Dr. Jacklich did not use either contradiction matrix, but rather used all 40 principles, with the following comments:

- *“Just because a principle is used frequently doesn’t mean it is the best one for my problem”*
- *“Sometimes the principle I hadn’t been thinking of gives me the best idea.”*
- *“The principles work best if they make the design more ideal—and even better if the production process uses existing resources! Remember, Special Products is a small business, and the less we spend on tooling up for a new product, the better.”*

Similarly, his use of the concept of resolution of physical (inherent) contradictions uses the core concepts of TRIZ, but not the details of the separation principles. As shown in figure 12, most commonly the techniques of stating the contradiction as a physical contradiction helps clarify the actual problem to be solved. This is similar to the ARIZ technique of exaggerating the contradiction, and has the same effect of clarification.

The refinement of the circumferential filing technique continued through several more generations shown in figures 13, 14, and 15. The number of files has been reduced to one—with the use of sonic-speed (300Hz) motion instead of the 5 Hz that the dentist can do with hand motion; a very fine file can be used, with no changes required. Figures 13 and 14 show the progression from a modified commercial “engine” (Sonicare™ toothbrush base) to a contra angle instrument powered and controlled by standard dental office systems, with a floating clutch to prevent the file jamming and breaking if the dentist misjudges the direction of the root’s curve. During the development of this article, some of the users complained that the new system is too fast, so Dr. Jacklich modified the cam to make it run at ¼ the original speed, then modified the new cam to make it fit within the existing housing.

Figure 15 shows the Fine-Cut File on the left and a conventional file on the right. The very small interflute distance combined with the 300 Hz motion makes tooth preparation very fast. In theory, one small file for all cutting and for probing, simplifying the endodontic method. By reshaping the flutes of the file so that it cuts on the up-stroke, Dr. Jacklich uses TRIZ principle 13 (*Do it in reverse*) to combine two functions, principle 5 (*Merging*) and again achieves objectives that benefit the patient, the dentist, and Special Products, Inc.

1. The dentist works faster, increasing productivity, while finishing the canal cleanly, with virtually no possibility of breaking the tool in the canal (a frequent problem with rotary

cutting, which then necessitates enlarging the canal to remove the broken tool, destroying a healthy part of the patient's tooth.) /Lit 1/ The dental literature has many articles on the details of whether stainless steel or NiTi files are better, and which can withstand 540° or 720° of rotation without breaking after jamming. The longitudinal motion of circumferential filing entirely eliminates those arguments.

2. The patient spends less time, increasing comfort and satisfaction, which results in increased recommendations of other patients to the dentist.
3. The dentist buys more files from Special Products, Inc.
4. The dentist recommends the entire system to friends, who become customers of Special Products, Inc.

Conclusion

This is an anecdotal case study, and in the words of TRIZ consultant Ralph Czerepinski, "The plural of anecdote is not DATA." Nevertheless, it is a persuasive set of anecdotes, that demonstrate that even beginner level TRIZ, used with few of the formal tools, can have powerful benefits for the inventor and for the entrepreneur.

Don't look for Dr. Jack Jacklich's inventions in the patent system. He has decided to avoid the time and expense of patenting and concentrate his energies on rapid development, deployment, and continuous improvement. It is appropriate to close this paper with his words on innovation, speed, and company size:

"Regardless of patents, big companies have the legal resources to steal anything a small company can do. My theory is to keep innovating, and keep innovating faster, so that I can be producing the next generation systems while the big companies are still changing their tooling for the last generation. TRIZ makes me ask better questions about my own products and techniques. TRIZ makes it easy to move faster and faster and faster."

Literature

- /Lit 1/ Jacklich, J. 2003 <http://www.betterendo.com>
- /Lit 2/ American Association of Endodontists 2003. <http://www.aae.org/patient.html>
- /Lit 3/ Domb, E. "TRIZ for Non-Technical Problem Solving" April 2003 TRIZ Journal <http://www.triz-journal.com>. First published in the proceedings of the 3d European TRIZ Kongress, Zurich, March 2003.
- /Lit 4/ Domb, E. "How to Help TRIZ Beginners Succeed" April 1997 TRIZ Journal. <http://www.triz-journal.com>.
- /Lit 5/ There are 10 collections of applications of the 40 Principles available in the TRIZ Journal, and more available in a variety of textbooks. Go to <http://www.triz-journal.com>, then click the bar "Matrix and 40 Principles" on the home page. Many companies also collect their own versions of the 40 Principles for internal use.
- /Lit 6/ Altshuller, G.S. Reprinted in <http://www.triz-journal.com>, July, 1997.
- /Lit 7/ Mann, D., Dewulf, S., Zusman, A., Zlotin, B. **Matrix 2003**. CREAX Publications, 2003.



Slide 1

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**Ellen Domb, Ph.D. and
John "Jack" Jacklich, D.D.S**

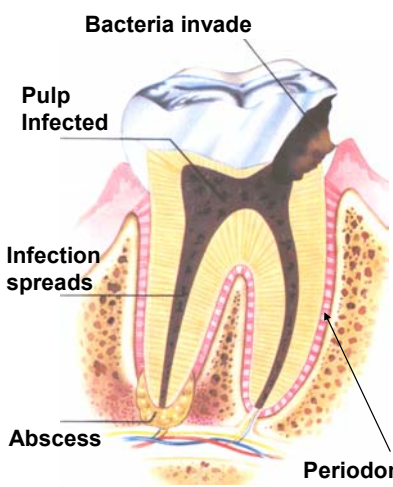
**PQR Group
Upland CA USA**

Aachen, November 12, 2003



  **Figure 1**

Slide 2

Introduction to Endodontics



- “Endodontic”—from the Greek for “inside” and “tooth”
- Dentist removes diseased pulp tissue from roots, treats infection, seals tooth.
- Roots are curved, varying diameters, varying cross-sectional shapes, branching
- Dentist must avoid pushing infected tissue out of the tooth into surrounding tissue.

  **Figure 2**

Root Geometry Makes the Cleaning Process Difficult



- Branching
- Tapering
- Non-uniform tapering
- Non-circular cross-section, changing along the length of the canal
- Varying length

Procedure is being conducted in the warm, moist, breathing, sensitive human mouth



Figure 3

Endodontic Inventions, Dr. Jacklich, Special Products



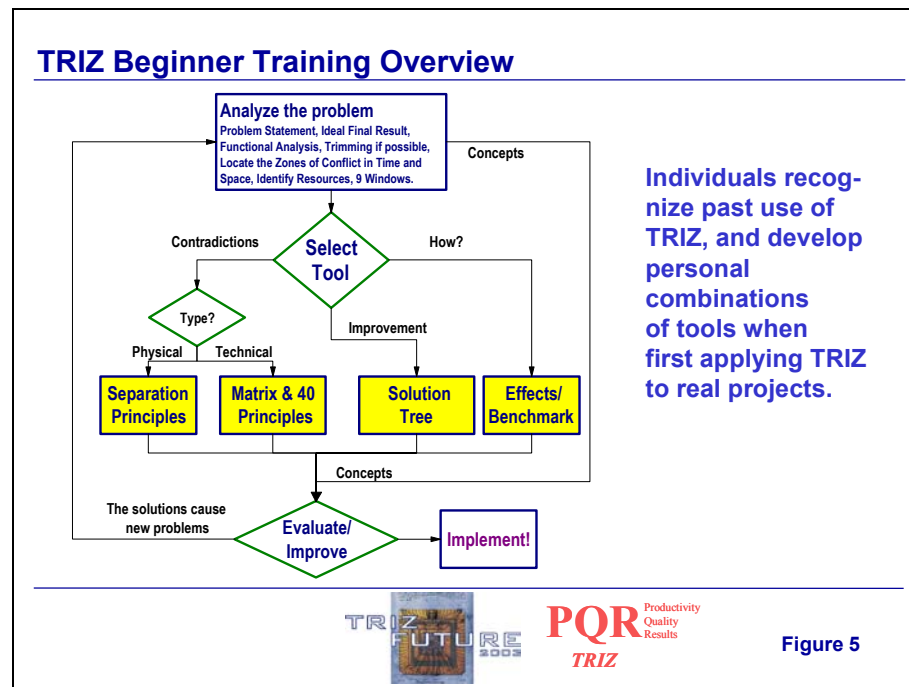
1972	Washed field technique, using existing instrumentation
1978	Precision Endo Syringe
1982	PDL (Periodontal Intraligamentary) Syringe
1987	Multi-Mode Endo Syringe
1997	Fine-Cut Endo Contra Angle
2003	Fine-Cut Endo Cartridge Syringe

Since beginning to study TRIZ in 1997, Dr. Jacklich has improved all his earlier inventions. New inventions go from concept to prototype to production much faster, and much more frequently.

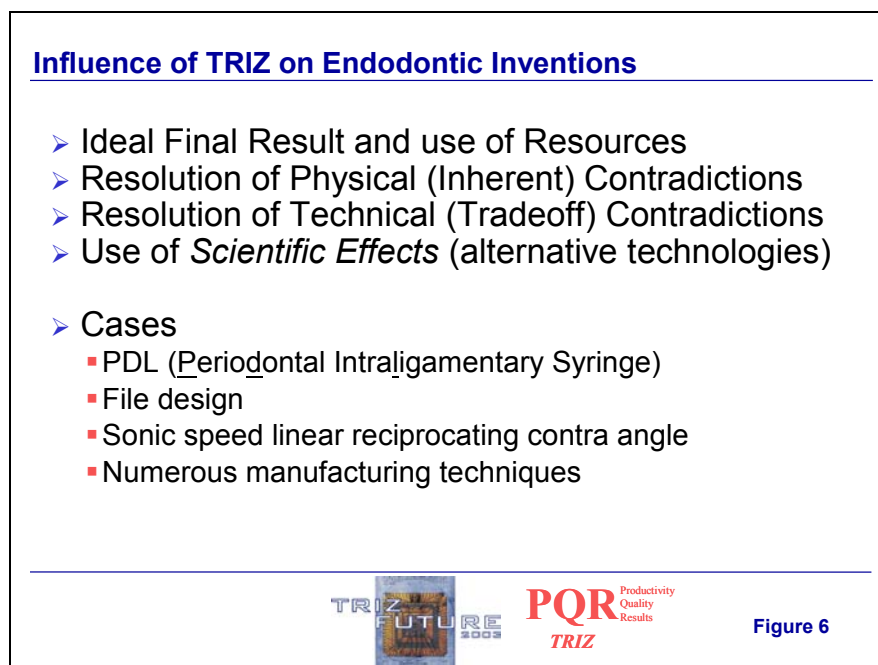


Figure 4

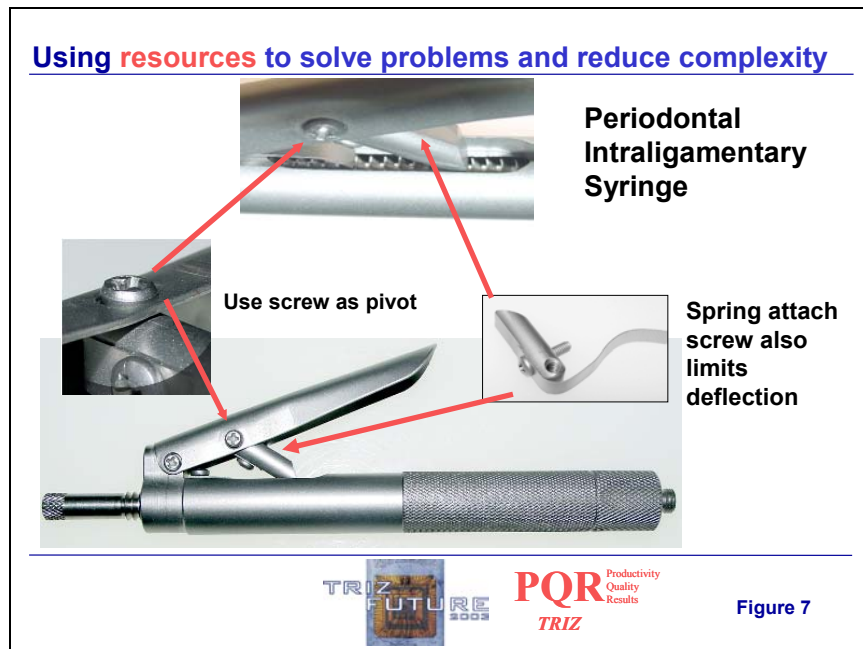
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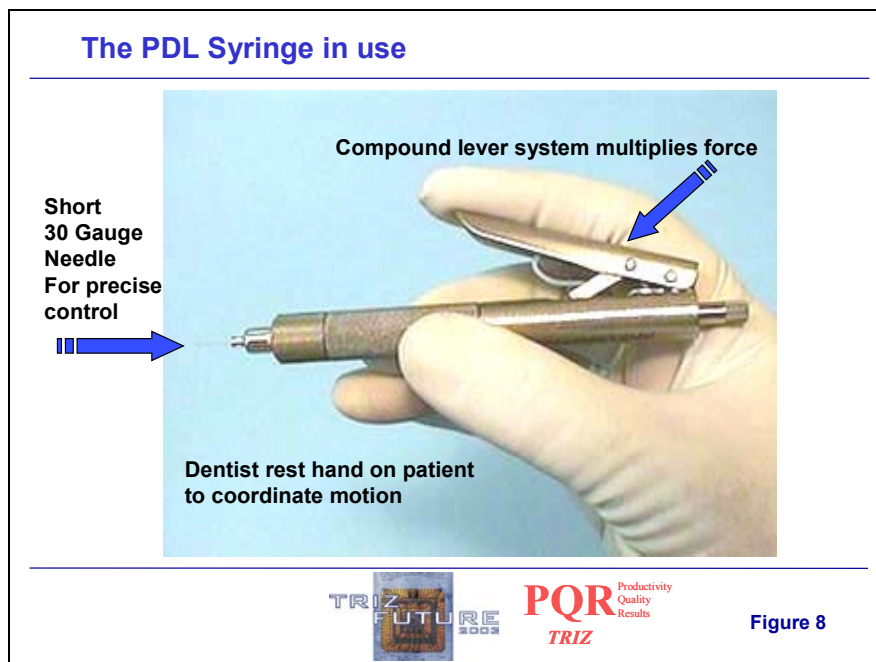
Slide 6



Slide 7

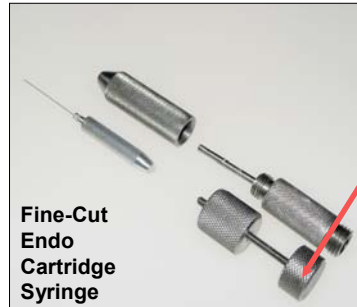


Slide 8



Using **effects** (borrowed technology from other applications)

Adapt micrometer for precision dispensing of material in increments as small as 1/1000 of an inch expelling cement in quantities as small as 0.00009cc.



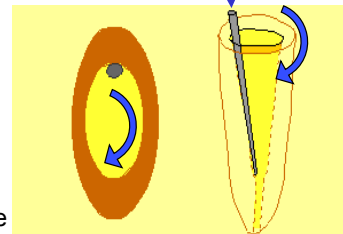
Fine-Cut
Endo
Cartridge
Syringe



Figure 9

Resolving technical and physical contradictions

- Hand or mechanical filing requires many file changes to clean out the diseased tissue at each diameter
- **Technical contradiction:** Cleaning gets better but convenience gets worse.
- **Solution: Circumferential Filing:** use curvature (Principle 14, Spheroidality). Helical broach opens the canal from the top, requires only 2 changes of file, and reduces dramatically, increasing both the dentist's productivity and the patient's comfort.



Typical
hand-held
endo file



Figure 10

Resolving Technical Contradictions

- **Many possible technical (tradeoff) contradictions:**
 - Volume vs. ease of operation or time or productivity
 - Quantity of material vs. ease of operation or time or productivity
 - Manufacturing (in this case Production) precision vs. ease of operation or time or productivity
- **Used all 40 principles, not the Contradiction Matrix**
 - “Just because a principle is used frequently doesn’t mean it is the best one for my problem”
 - “Sometimes the principle I hadn’t been thinking of gives me the best idea.”
 - “The principles work best if they make the design more ideal—and even better if the production process uses existing resources!”



Figure 11

Resolving Physical Contradictions

- **Expressing the situation as a physical (inherent) contradiction clarifies the nature of the desired solution by exaggerating the situation**
 - Statement of the contradiction: *I want to clean the canal but I don’t want to clean the canal*
 - Thought process: I really do want to clean the canal
 - Statement of the contradiction: *I want to use many files but I want to use no files*
 - Thought process: I really don’t want to use many files—what I want is the effect of using many files but not having to change the files, and inventory the different files.



Figure 12

Combining functions and trimming, using resources

- Constructed an adapter for a standard consumer product—took the idea from concept to production in one weekend!
- 300 strokes/second vs. 5 strokes/second for manual filing
- Easy to manipulate for circumferential filing.
- Reduces number of files needed from 2 to 1. Because of the speed, one very small file can be used instead of a progression.

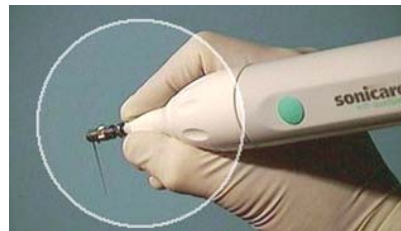
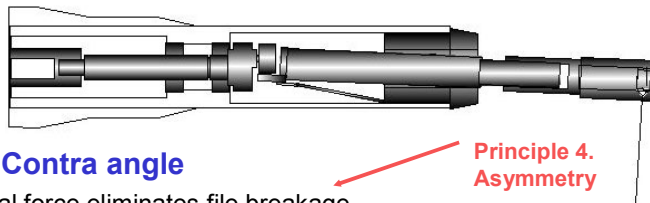


Figure 13

Combining functions and trimming and using resources



➤ Fine-Cut Contra angle

- Differential force eliminates file breakage
 - Leaf spring-forward, cam-backward
- Rotation translates into vertical motion
- Fits standard dental office power and control systems
 - Foot control for on/off
 - Same diameter and hand position for stability
- More “traditional” for the dentist than the adapted Sonicare™ unit (The customer is a resource of the system!)

Principle 4.
Asymmetry

Principle 15
Flexibility

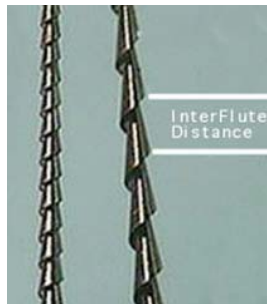
Principle 14
Use Curves

Use what is
there, don't
add something
new.

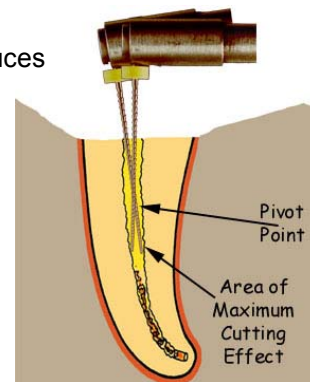


Figure 14

File Geometry Increases Ideality



- Files are used for both cutting and probing
- Low helical angle adapts to canal geometry
- Probe will get stuck-new design cuts on upstroke, unsticking itself
- Sonic speed cutting reduces need to use large files for speed, improves geometry of finished canal. Probing is done at 1/300 mm increments, using one file



The canal shapes itself!



Figure 15

Conclusions

- TRIZ beginner-level training can have a significant impact on design of products and the processes for creating them
- Company size is no barrier.

Specialty Products, Inc.



	Dentist/ engineer	Machinist/ tool designer	Marketing manager
TRIZ training	1997	none	2003
TRIZ thinking	yes	yes	yes



Figure 16

Profile of Lecturer

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Brief Résumé & job descriptions:

1946	Birth
1968	Bachelor of Science (Physics), Massachusetts Institute of Technology
1969	Master of Science, (Physics) University of Pennsylvania
1974	Ph. D. (Physics) Temple University
1974-6	University of Nebraska
1976-79	Assistant Professor, Harvey Mudd College, and Research Fellow, California Institute of Technology
1979-1990	Aerospace/Defense Industry, Engineering and Management of Engineering, Information Technology, and Quality Improvement
1990-present	Consultant, PQR Group
1996-present	Founder and Editor, the TRIZ Journal

TRIZ is Dr. Domb's 6th career: she has been a physics professor, an aerospace engineer, an engineering manager, a product line general manager, and a strategic planning/quality improvement consultant. She has been teaching and consulting on the use of TRIZ and on combining TRIZ with other methods, especially Six Sigma, for 8 years. She is a popular lecturer at conferences around the world.

Profile of Lecturer

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Brief Résumé & job descriptions:

1962 DDS, Loyola University Dental School, Chicago IL USA
1962-72 Dental practice
1970-74 Associate Professor in Fixed Prosthodontics at Loyola Dental School
1974 Associate Professor and Assistant Director of Rural Dentistry Program University of Illinois
1976 Began teaching "Automated Endodontics" seminar
1977 First invention "Precision Endo Syringe"
1976-7 Founded Special Products, Inc. to market endodontic products and Continuing Education Centers of America in 1976 to deliver seminars. First to do traveling participation course.
1985 Fine-Cut Sonic Adapter which transmitted sonic or ultrasonic vibration from a sonic or ultrasonic dental scaler to the endo file. Invented Fine-Cut file blade design
1992 Sonicare toothbrush to do endo with Fine-Cut Adapter
1998 Invented Fine-Cut Endo Contra-Angle first shown at the Internet Dental Forum in San Diego.
1997-03 Continuous improvement and simplification of all products using TRIZ
2003 Fine-Cut Endo Cartridge Syringe