Laser Dentistry—— Past to Present

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_Abstract

The first laser in the world designed specially for general clinical dentistry debuted in Germany in 1989. Over the past twenty years many different laser wavelengths and units have been marketed worldwide. The author's long-time involvement in the dental laser industry gives him a unique perspective. In this two part series the author will first discuss the historical development of laser dentistry. The second part of the series will focus on the worldwide dental laser marketplace and the important research that helped obtain the first U.S. Food and Drug clearances for various laser wavelengths.

Today's dental lasers have their roots founded in the field of quantum mechanics formulated during the early 1900's. That is when Albert Einstein mathematically demonstrated the possibility that portions of the electromagnetic field could be stimulated to emit amplified light. However, it took over forty years for that principle to become a reality. American physicist Charles H. Townes in the early 1950's, amplified microwave frequencies by the stimulated emission process (maser). Then Schawlow and Townes (1958), wrote a paper in which they discussed extending the maser principle to the optical portion of the electromagnetic field. Finally Maiman (1960) inserted a ruby rod into a photographic flash lamp turned the switch and light amplification by stimulated emission of radiation (LASER) became a reality.

Shortly after Maiman's scientific break-through researchers began studying the feasibility of using this new technology for dental procedures. We will examine in a two part series, the present worldwide dental laser marketplace and the more significant efforts of dental researchers that not only helped to bring the various lasers to the dental market but also developed the basic laser safety parameters for all the hard and soft tissue clinical applications used today, but first let us look at the historical aspects of the first dental laser brought to market.

My brother and I submitted our first application to the United States Patent and Trademark Office (USPTO) in 1983 and two years later the USPTO granted our patent for a method of using a specific laser to remove surface tooth decay and in 1986, we started a small company (American Dental Laser [ADL] Birmingham, MI, USA) and sold our first laser in 1989. Over the next two years, ADL introduced our dental laser, the dLase 300, a pulsed 3 Watt Nd:YAG (Neodymium:Yttrium Aluminum Garet) laser with an emission wavelength of 1,064 nanometers, throughout North America, Germany and Japan.

From this small start-up company the dental laser market has continued to prosper and grow and today both local and international dental manufacturers and distributors offer a variety of dental laser wavelengths to their customers with market penetration of the units closely approaching double digits in several countries.

It sounds so simple: Obtain a patent, start a company and an industry will soon follow. However, it was anything but simple.

My brother, William D. Myers, M.D. was one of the first US ophthalmologists to use a laser in his private practice for posterior capsulotomy procedures and six years my senior had his M.D. degree before I graduated from dental school. After my graduation in 1973 he continued to ask me about the use of lasers in dentistry and would invite me to his office to observe laser procedures. His patients would go home shortly after a three minute laser treatment and resume normal activities. The conventional surgical procedures would require an overnight stay at the hospital. Needless to say I was very impressed and "hooked"! How can we use lasers in dentistry?

During the late 1970's, I gathered all the data on dental laser research that was available and found that from the mid 1960's through the mid 1970's, Stern and Sognnaes, Lobene and Fine, Kinersly, Gordon, Taylor and Adrian were very active researchers and all these groups experimented with the only laser available at the time—the Ruby laser. Their results were not favorable for clinical dental laser applications due to irreversible pulpal necrosis caused by the lasers thermal properties. However, in this same time period, other lasing mediums were being developed. Adrian et. al. (1971) used a Ruby laser to measure threshold response in dogs' incisor teeth and found that energy densities great enough to cause enamel cratering, cause total pulpal necrosis. He (1977) repeated this threshold experiment using a Neodymium laser and found that even at energy densities great enough to cause enamel cavitation no pulpal necrosis occurred.

Adrian's work was very exciting for me because my brother's ophthalmic laser was a mode-locked Nd:YAG and for the next two years beginning in 1979, my brother and I experimented with freshly extracted human teeth. I had an ophthalmic Nd:YAG in my dental office for over a year experimenting whenever possible since we both had full time practices. We were looking for surface modification changes on lased teeth and after obtaining SEM samples we would have a dental histologist review various samples of control, acid etch and lased teeth and with all of the collected historical data plus our own data by 1981 we began collecting comparison data utilizing different laser wavelengths, courtesy of several local hospitals.

By 1983 we were convinced we had collected enough sound invitro data to submit an article to the Journal of Prosthetic Dentistry and file for a patent with the USPTO which was published (1985) and patent granted (1985) two years later.

The following two years were spent locating a manufacturing company that was willing and able to transform what we had on paper into a working unit. We literally met and had discussions with laser manufacturing companies throughout the world. In the end we contracted with another small startup company, Sunrise Technologies (Fremont, CA, USA).

We had three other critical issues; form a company, obtain funding and most importantly get a clearance from the Food and Drug Administration (FDA). The company, American Dental Laser (ADL) was formed in 1986, and we hired a person to run the company and obtain private funding.

The first prototype was built in 1987(Fig. 1) and more testing and experimentation were conducted to obtain critical data for our FDA submission. In 1988 ADL and Sunrise submitted both a hard and soft tissue application to the FDA and in 1990 the FDA granted us a general oral soft tissue clearance for the dLase 300. Over the next several years ADL was granted several more patents and marketing clearances all of which were based on evidenced based research, thanks to numerous dental researchers and clinicians from around the world.

The first international showing of the dLase 300 occurred in 1989 at the International Dental Show (IDS) held in Stuttgart, Germany. Our exhibit was a success with both German dentists and distributors showing great interest in this new dental technology. Thus the beginning of the German dental laser market.

ADL helped form a German dental laser study club in 1991 to better train and educated the dentists who had purchased the dLase 300. This group formed the Deutsche Gesellschaft fur Laserzahnheilkunde e.V. (DGL) which held its 18th Annual Congress this year in Cologne, Germany. My congratulations to DGL!

American Dental Laser helped numerous other dental laser study clubs get started in Europe, Asia and North America in the early 1990's. Some of whom, like DGL, formed their own academies that are still in existence today. These academies have incorporated all laser wavelengths in their scientific sessions and have supplied important research data throughout the last twenty years.

In conclusion it is difficult to believe thirty years have past since lasing that first extracted tooth. It has been my good fortune to witness the birth and growth of a new dental technology and had the opportunity to meet many outstanding dental researchers, academicians and clinicians across the globe. It has been an exciting and fulfilling personal journey with many enduring memories.



Fig 1_The first working prototype of the first dental laser.

_Worldwide Dental Laser Market and Research

The Food and Drug Administration granted market clearance for the first dental laser in May, 1989. It was a pulsed Nd:YAG (Neodymium:Yttrium Aluminum Garnet) laser. During the next eighteen months the FDA cleared two other Nd:YAG's, a Carbon Dioxide (CO_2) and an Argon Ion laser for general intraoral soft tissue surgery.

During the past twenty years the FDA has cleared hundreds of laser devices for dental use for over fifty different laser manufacturers for curing of composite materials, tooth whitening, sulcular debridment, caries removal and cavity preparation, aphthous ulcer, herpetic lesion treatment, diagnosis of dental caries and calculus as well as endodontic procedures and cutting and recontouring of osseous tissue.

FDA clearances are important for three entirely different reasons:

1. Demonstrates the device is safe and effective.
2. Allows the distributor/manufacturer to advertise and market the cleared device.
3. Most dentists from outside the United States are more willing to purchase a laser if it has FDA clearance.



Because of these factors the FDA has had a major influence in the worldwide growth of the dental laser market.

Throughout the 1990's two US dental laser manufacturers were very instrumental in growing the worldwide dental laser market. In the early 1990's ADL changed its name to American Dental Technologies (ADT) to reflect its growth of new dental products and was the worldwide leader in dental laser marketing. Starting in the middle 1990's Biolase Technology (Irvine, CA, USA) became the leader in worldwide dental laser marketing and due to their combined marketing efforts, dentists became more aware of the advantages of laser dentistry. Both small startup companies and established medical laser manufacturers took note of the growth and entered the dental marketplace. By the year 2,000, most dentists in the world could go online, talk to their local dental distributor or attend a lecture to learn more about dental lasers or visit the International Dental Show (IDS) and see no fewer than 30 different lasers on display. The world wide dental laser market continued with slow but steady growth in the early 2000's, however, the market was missing one last key factor—a large international dental manufacturer willing to put their stamp of approval on laser technology. That changed when not one but three such companies obtained FDA marketing clearances. The companies were Ivoclar Vivadent (Schaan, Principality of Liechtenstein) Sirona Dental System GmbH (Bensheim, Germany) and KaVo Dental GmbH (Biberach, Germany).

These three companies supplied the necessary marketing power to place awareness of dental lasers at the same level of most other dental equipment. They also helped to solidify dental lasers in four major markets.

Table I shows the market penetration of dental lasers in the four major markets of the world. While dentists in all countries have purchased this technology, their market penetrations are below 5%. It is interesting to note the differences in laser wavelengths that are popular in the four major markets. Japanese dentists are not very interested in diode lasers or Erbium hard tissue lasers and during the last five years the CO_2 laser has out sold the Nd:YAG laser. In the United Sates both diode and Erbium lasers are very popular. Diode technology is also popular in Germany and Italy, while for the most part only German dentists are buying hard tissue Erbium lasers.

Table 1_ Market Penetration of dental lasers in the four largest markets of the world (from the Institute for Advanced Dental Technologies with permission).

Country	# Dentists	% Market Penetration
Japan	140,000	16–18%
USA	60,000	36–38%
Germany	60,000	8–10%
Italy	55,000	6–8%

_Dental Laser Research

Every year since the early 1990's hundreds of dental laser research abstracts and articles are published as well as oral and poster presentations given. Their topics have covered every aspect of clinical dentistry and have assisted clinicians and manufacturers to refine their techniques and instruments. This section will concentrate on key research that helped bring laser technology to the dental marketplace.

_Nd:YAG Lasers

White et.al (1991) was the principle reason the FDA cleared to market the first dental laser in May, 1990. Their initial work involved comparing laser to scalpel gingivectomies. Their results indicated that the Nd:YAG could be used successfully for general intraoral soft tissue surgeries and were well tolerated without local anesthesia and with minimal bleeding compared to scalpel surgery. White's group also provided laser safety guidelines regarding instrument settings and clinical procedural techniques to assure safe and effective treatment outcomes.

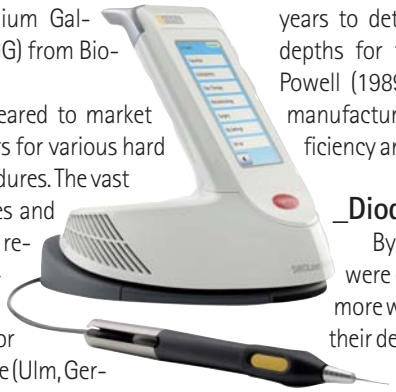
Research provided by Gutknecht et al. (1997) and Neill and Mellonig (1997) was instrumental in obtaining the first FDA periodontal laser therapy market clearance. Both groups compared root planing and scaling to laser therapy (curettage) plus root planing and scaling in adults with moderate to severe periodontitis. While both studies examined bacterial and recolonization reductions, Neill also recorded changes in Gingival Index (GI), Gingival Bleeding Index (GBI), Probing Dept (PD), Clinical Attachment Level (CAL), and Tooth Mobility (TM). Both groups found greater bacterial reduction and slower recolonization in site receiving laser therapy. Neill also found greater improvements in lased sites for GI and GBI. Both groups concluded that the adjunctive use of the Nd:YAG may have clinical advantages over scaling and rooting alone as a mechanical approach to non surgical periodontal therapy.

_Erbium Lasers

The Centauri Er:YAG (2.94 microns) dental laser from Premier Laser Systems (Irvine, CA, USA) was granted the FDA's first marketing clearance (May, 1997) for hard tissue procedures including caries removal, cavity preparation and surface modification of enamel and dentin. In part, the FDA relied on research supplied by Cozean et. al (1997). Their work consisted of two phases at five clinical sites. In Phase I the clinicians prepared teeth that were scheduled for extraction. The teeth were prepped and filled then extracted at various time intervals for histological examination of pulpal changes. Phase II involved prepping and filling teeth and following patients' responses over an eighteen month period. In both phases the patients were randomly divided into receiving either laser or high-speed air turbine treatment. The collected data showed that compared to the high-speed drill the Er:YAG was safe and effective for the indicated hard tissue procedures.



Eversole and Rizoiu (1995, 1997) conducted various invitro animal and in vivo human studies that were instrumental in obtaining FDA hard tissue marketing clearance (Oct. 1998) for the Erbium Chromium: Yttrium Scandium Gallium Garnet laser (Er.Cr:YSGG) from Biolase (Irvine, CA, USA).



To date the FDA has cleared to market fourteen other Erbium lasers for various hard and soft tissue dental procedures. The vast majority of these clearances and US Patents have cited the research of two individuals—Raimund Hibst and Ulrich Keller from the Institute for Laser Technology in Medicine (Ulm, Germany) and the dental school at the University of Ulm (Ulm, Germany) respectively. Their initial experiments (1989, 1991, 1993) laid the foundation for all other Erbium research over the past twenty years. And it was their research that directly helped develop the Keylase Erbium laser (KaVo Dental GmbH, Biberach, Germany). Any dentist that utilizes an Erbium laser in their practice owes a debt of gratitude to Hibst and Keller's ongoing dedication to dental laser research.

_Carbon Dioxide (CO_2) Lasers

Luxar Corp. (Seattle, WA, USA) received the FDA's first CO_2 soft tissue clearance in May 1991. Presently over twenty different units from various companies have been cleared by the FDA.



While sales were brisk in the early 1990's their popularity has decreased over the last decade (except in Japan). However a new generation of Ultra pulsed CO_2 lasers may reserve that trend.

CO_2 lasers have been used successfully for decades in medicine for various soft tissue surgeries so medical laser manufacturers had an easier time obtaining FDA clearances for soft tissue dental procedures. While there was no key research required for the clearances there were dental researchers that increased the awareness of this wavelength (10.6 microns) in dentistry. Fisher et. al (1983) Frame (1984) Pick (1985) and Miserendino (1988) all demonstrated the laser's advantages over conventional surgical techniques.

_Argon Lasers

In 1991, HGM Medical Laser Systems (St. Lake City, UT, USA) obtained FDA clearance for soft tissue procedures and curing composites. Soon other Argon manufacturers were cleared to market for curing composites and tooth whitening. Soon after LED curing lights became available and argon laser sales drastically decreased. Presently no Argon Ion laser is being marketed for dentists.

However key research was conducted for over the years to determine proper curing times and curing depths for the various systems by Blankenau and Powell (1989, 1999). Their research allowed various manufacturers to refine their units to maximize the efficiency and safety for curing composites.

_Diode Lasers

By the time Diode lasers (.810.980 microns) were cleared to market (Dec. 1995) the FDA was more willing to allow manufacturers to show that their devices were substantially equivalent to previously market cleared devices. The key research supplied to the FDA for the Nd:YAG, Erbium and CO_2 lasers indicated to the FDA that diode lasers were equivalent and thus granted FDA market clearance.

_Conclusion

This two part series attempted to familiarize the reader with historical data that helped develop today's worldwide dental laser industry. Today, laser manufacturers and researchers are examining new wavelengths and accessories that will allow dentists continued ability to deliver state of the art care to their patients. As dental laser sales continue to increase, even more revenues can be applied to future research and development of new laser technologies. In the last twenty years dentistry has witnessed more technological advancements than the previous one hundred years. The next twenty years promised to be even more bountiful and dental lasers will continue to be part of that excitement.

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The whole Literature list can be requested from the editorial office.

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