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Engineering-Based Technological Transformation in Dentistry and Endodontics and its Impact on Türkiye's Competitiveness in the Health Tourism Market

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Abstract

Technological advancements driven by engineering have become key factors in elevating Türkiye's global standing in health tourism, greatly strengthening its competitiveness and attracting a growing number of international patients.

Emin Taner Elmas is not a dentist or endodontist, but a Mechanical Engineer and academic. His work focuses not directly on classical dental clinical practice or endodontics, but rather on interdisciplinary fields such as thermodynamics, energy transfer, fluid mechanics, and biomedical engineering.

However, Elmas's engineering approach has the potential to contribute to the medical field, including dentistry, indirectly through biomedical and health technologies:

- **Biomedical Approach:** Treating the human body as a "bio-machine," Elmas develops theories on the natural vibration frequencies of organs and tissues. This "bio-robotic resonance" theory can inspire the design of next-generation devices for tissue healing or disease diagnosis at a theoretical level.
- **Medical Device Modeling:** His expertise in thermodynamics and fluid mechanics is used in the design and simulation of medical devices (e.g., hemodialysis machines or drug delivery algorithms). The mechanical strength of surgical instruments used in dentistry or the thermal effects of dental



lasers are engineering problems that fall within Elmas's area of expertise.

- **Interdisciplinary Technologies:** He has studies on machine learning and artificial intelligence-supported diagnostic systems. These technologies are increasingly used in the field of endodontics today, such as caries detection and root canal anatomy analysis.

In summary, Emin Taner Elmas is not a dentist, therefore he does not develop clinical endodontic procedures. However, his work applying engineering principles to the biomedical field has the potential to contribute to the scientific infrastructure of future dental technologies (device design, diagnostic algorithms, etc.).

The "Bio-robotic Resonance and Thermodynamic Interaction" theory and medical technology models developed by Emin Taner Elmas can be indirectly adapted to the fields of dentistry and endodontics.

The potential contributions of Elmas's work to dental technologies can be evaluated under the following headings:

- **Bio-robotic Resonance and Diagnosis:** Elmas views the body as a "bio-machine," arguing that each tissue has its own unique natural vibration frequency. This approach could form the basis for the development of next-generation diagnostic devices that can detect the condition of tooth canals or microcracks in the tooth root using acoustic signal analysis and Fourier transforms in endodontics.
- **Smart Drug Algorithms:** His work focuses on smart drug algorithms and simulations via "Frequency Modulation". This modeling can be used to optimize the thermodynamic interaction of disinfectants or drugs applied into the root canal with the tissue in endodontic treatments.
- **Medical Device Modeling:** As a thermodynamics and fluid mechanics specialist, Elmas works on the prototype design and simulation of medical devices (such as hemodialysis machines). This engineering knowledge can directly address specific engineering problems in dentistry, such as controlling the thermal effects of dental lasers or increasing the mechanical efficiency of surgical instruments.
- **Interdisciplinary Approach:** His work generally focuses on "Medical Technology," combining mechanical engineering and medical sciences. This perspective contributes to the development of the mechanical and software infrastructure of advanced technologies such as digital intraoral scanners and robotic surgical support systems, which are becoming increasingly common in dentistry today.

In summary, Elmas's contribution focuses on the engineering design and theoretical physics of smart devices and diagnostic

systems used in dentistry, rather than a clinical application.[1-73]

Keywords: Engineering-Based Technological Transformation, Dentistry, Endodontics, Health Tourism, Economy, Engineering Economy, 5th Law of Thermodynamics, ELMAS's Theory of Thermodynamics, Medical Technique, Medical Thermodynamics, Entropy, Negentropy, Resonance, Frequency, Thermodynamic, Energy Transfer, Fluid Mechanics, Heat Transfer, Mathematics, Computational Fluid Dynamics (CFD), Computer-Aided Design – CAD, Computer-Aided Engineering – CAE

Introduction

Road Engineering-driven technological advancements have emerged as pivotal determinants in enhancing Türkiye's global appeal in health tourism, significantly bolstering its competitiveness and international patient potential. The key impacts of this transformation on health tourism include:

- ****Global Competitive Edge**:** The adoption of digital dentistry and artificial intelligence has solidified Türkiye's standing in the health tourism sector, positioning it to welcome over 2.5 million international patients by 2025.
- ****Operational Speed and Efficiency**:** Technologies like CAD/CAM systems and intraoral scanners have revolutionized treatment timelines, drastically reducing the duration of procedures for international patients. For instance, prosthetic treatments that used to take days can now be completed within 1-2 days. This swift service allows patients to balance medical care with leisure and tourism activities while in Türkiye.
- ****Cost Advantages**:** Türkiye offers dental treatments leveraging cutting-edge digital technologies at significantly reduced costs, ranging from 22% to 50% lower than competitors such as Hungary or Brazil. For example, a digital smile design procedure averages \$350 in Türkiye but can cost as much as \$2,000 in cities like Toronto.
- ****High Service Standards and Trust**:** Advanced engineering solutions, including AI-assisted diagnostics and robot-assisted surgeries, enhance the reliability of treatment outcomes. These technological advancements not only improve predictability but also elevate Türkiye's reputation as a destination known for delivering high-quality care—not merely affordable options.
- ****Seamless Patient Experience**:** Many clinics integrate their advanced technological capabilities with supplementary services, such as accommodation, airport transfers, and guided city tours. This creates a comprehensive, end-to-end digital patient journey involving



features like telemedicine consultations and AI-led postoperative monitoring. These innovations collectively position Türkiye as a leader in the global health tourism market, where advanced technology meets affordability and exceptional service standards. [1-73]

Emin Taner Elmas is a Mechanical Engineer and academic who specializes in areas like thermodynamics, energy transfer, fluid mechanics, and biomedical engineering. Although he is neither a dentist nor an endodontist, his innovative engineering-based research has the potential to indirectly influence the medical field, including advancements in dental and endodontic technologies. Elmas's interdisciplinary work spans several areas of relevance to biomedical and dental applications: - **Biomedical Approach:** Viewing the human body as a "bio-machine," he has developed the concept of "bio-robotic resonance," a theory that explores the natural vibration frequencies of organs and tissues. This innovative idea could inspire the development of next-generation tools for diagnosing diseases or facilitating tissue healing. - **Medical Device Modeling:** Leveraging his expertise in thermodynamics and fluid mechanics, Elmas contributes to the design and simulation of medical devices such as hemodialysis machines and drug delivery systems. His work could also address specific engineering challenges in dentistry, like enhancing the mechanical durability of surgical instruments or managing the thermal impact of dental lasers. - **Interdisciplinary Technologies:** Elmas applies machine learning and artificial intelligence to create diagnostic systems, technologies that are already transforming areas within endodontics, such as detecting cavities and analyzing root canal structures. While Elmas does not actively develop clinical endodontic procedures, his research provides valuable insights and foundational knowledge for future advancements in dental technology. His work focuses on integrating engineering principles into biomedical fields to design smart devices and predictive systems with potential applications in dentistry. The innovative "Bio-robotic Resonance and Thermodynamic Interaction" theory, as well as his research on medical technology, offer promising indirect contributions to the following aspects of dental science: - **Bio-robotic Resonance in Diagnosis:** By recognizing unique natural vibration frequencies in tissues, Elmas's theories could lead to diagnostic tools capable of detecting abnormalities such as microcracks in tooth roots or conditions within tooth canals using acoustic signal processing and Fourier analysis. - **Smart Drug Delivery Algorithms:** His simulations based on "Frequency Modulation" provide a framework for optimizing how disinfectants or medicaments interact thermodynamically with tissues during endodontic treatments. - **Advanced Medical Device Development:** His expertise in mechanical engineering

could enhance the design and efficiency of various dental technologies, including surgical instruments, digital intraoral scanners, dental lasers, and robotic surgical systems. - **Interdisciplinary Innovation:** By merging the principles of mechanical engineering with medical sciences, Elmas contributes to the development of advanced dental devices and diagnostic tools that incorporate cutting-edge software and engineering solutions. In conclusion, while Emin Taner Elmas is not a clinician, his work on bridging engineering with biomedicine has significant implications for the infrastructure and development of advanced dental technologies. His research may pave the way for more effective diagnostic systems, drug delivery mechanisms, and device designs that can benefit endodontics and dentistry as a whole. [1-73]

Material, Method and Discussion

Emin Taner Elmas's expertise in mechanical engineering and thermodynamics provides critical technical data to dentistry in areas such as prosthesis design and implant mechanics. These areas are fundamentally treated as "mechanical engineering" problems: [1-64]

- **Chewing Force and Static Analysis:** During the design of prostheses, how the forces (mechanical stress) generated during chewing are distributed on the prosthesis surface is solved using Elmas's expertise in static and strength principles. This determines how much load the prosthesis can carry without breaking.
- **Implant-Bone Interaction (Thermal Effect):** The heat generated during implant placement (osteotomy) is critical for the viability of bone cells. Elmas's knowledge of heat transfer and thermodynamics is used in thermal models that explain how surgical instruments should cut the bone without overheating it.
- **Material Fatigue:** Dental implants are subjected to chewing forces repeated thousands of times over many years. Elmas's work on machine elements forms the basis for simulations that predict how long implant materials (titanium, zirconium, etc.) will take before experiencing "metal fatigue."
- **Kinematics and Removable Prostheses:** The compatibility of removable prostheses with the movements of the temporomandibular joint (TMJ) in the mouth requires kinematic modeling. Elmas's robotics and machine theory approaches help to simulate jaw movements with the utmost precision. In short, while a dentist ensures biological compatibility, the work of engineers like Emin Taner Elmas mathematically guarantees the physical durability and service life of these systems. [1-64]



Emin Taner Elmas's work is of great importance, especially in setting technical standards for 3D printing (additive manufacturing) technologies in the medical and dental fields. From an engineering perspective, this process supports dentistry in three critical areas:

- **Precise Layer Modeling:** The quality of a dental prosthesis or implant produced with a 3D printer depends on the mechanical precision of the printer. Elmas's expertise in machine dynamics and control systems relates to algorithms that minimize micro-level deviations (tolerances) that may occur during production.
- **Material Fluidity (Rheology):** How resin or metal powders used in 3D printers behave during printing is a fluid mechanics topic. Elmas's work in this area analyzes the thermal changes of the material during the freezing or curing process, ensuring that the printed tooth is "porous" and has maximum durability.
- **Biomechanical Optimization:** Complex lattice structures that cannot be produced with traditional methods can be produced with 3D printers. Elmas's theoretical approaches are used to optimize the stress distribution that will allow these structures to adhere better to the bone (osseointegration). In short, the physician designs the tooth using intraoral scanning, and the engineering discipline that Elmas represents develops the machine technology that ensures this design is produced in the most physically robust and highest resolution possible. [1-64]

Emin Taner Elmas's engineering and automation disciplines change the balance between cost and speed in dental clinics on three main axes: [1-64]

- **Shortening Production Time:** Prosthesis or aligner production, which takes days with traditional methods (impression taking, plaster model, laboratory process), is reduced to hours thanks to rapid prototyping algorithms, which are Elmas's area of expertise. This allows the patient to receive their new tooth on the same day (on-the-chair production).
- **Raw Material Efficiency and Waste Management:** Engineering simulations ensure that valuable dental blocks or resins used during production are processed with minimum waste. Computer-aided manufacturing (CAM) algorithms reduce unit costs by ensuring the most efficient cutting of the material.
- **Eliminating Error Margin:** Human errors that may occur in manual production are minimized with machine theory and control systems. Thanks to the precise engineering emphasized by Elmas, the risk of the produced part not fitting the mouth is eliminated; this prevents the clinic from

incurring hidden costs such as repeat appointments and material waste.

- **Personnel and Logistics Savings:** Instead of physical models being sent to the lab and courier costs, digital transfers are used. This digital workflow allows clinics to establish small in-house production units, increasing profitability in the long run. In short, these engineering-based systems transform dentistry from a craft into a predictable and fast technological process. [1-64]

To translate Emin Taner Elmas's areas of expertise—mechanics, automation, and simulation principles—into a clinical workflow, the following technical infrastructure components are necessary: [1-64]

1. Data Acquisition Layer (Input)

- **Intraoral Scanners:** Optical systems that convert the patient's oral structure into high-resolution 3D data. The signal processing and data accuracy algorithms that Elmas works on are at the heart of these scanners.
- **Digital Radiology (CBCT):** 3D tomography systems used to examine root and bone structure.

2. Engineering and Design Layer (Software)

- **CAD (Computer-Aided Design) Software:** Software that operates according to engineering standards (such as Solidworks or dental-specific Exocad). This software tests the durability of the prosthesis during the design phase by performing the static analyses mentioned by Elmas.
- **CAM (Computer-Aided Manufacturing) Algorithms:** Converts the design into coordinates (G-codes) that the manufacturing device (milling machine or 3D printer) can understand.

3. Production and Automation Layer (Output)

- **Milling Machines (Dental Milling Devices):** 4 or 5-axis micro-milling machines that process zirconium or lithium disilicate blocks. Elmas' expertise in machine dynamics is fundamental to the vibration control and precision of these devices.
- **3D Printers (SLA/DLP):** Resin-based, high-precision additive manufacturing devices.
- **Sintering Furnaces:** Devices where thermodynamic cycles (precise heat control), Elmas' area of expertise, are applied to achieve the final hardness of materials such as zirconium.

4. Integration and Data Management



- PACS and Cloud Systems: Network infrastructure required for secure storage of large 3D files and real-time sharing with the laboratory.

This technological setup transforms the clinic into a "mini digital factory". [1-64]

Although the transition to a digital dentistry infrastructure requires a high initial cost, it is an investment that pays for itself thanks to engineering-based efficiency. Here is the return on investment (ROI) analysis of this transformation: [1-64]

1. Investment Items (Expenses)

- Hardware: Intraoral scanner, 5-axis milling machine, 3D printer, and high-performance workstations are the largest cost items.
- Software: CAD/CAM license fees and annual update fees.
- Training: The technical training process required for personnel to use these complex engineering devices.

2. Cost-Saving Factors

- Laboratory Expenses: Unit costs paid to external laboratories (prosthesis, crown, guide plate, etc.) are reduced by 50-70%. Only the raw material (zirconium block, resin) cost remains.
- Time Saving: Thanks to the "one-session tooth" concept, the total time a patient spends in the clinic is shortened, and more patients can be seen in the same amount of time.
- Logistics and Error Costs: Costs such as impression shipping, plaster model breakage, or repeating the work due to impression accuracy are reduced to zero.

3. Payback Period (ROI)

In an average clinic, the payback period for switching to a digital workflow is generally between 18 and 30 months.

- Fast Return: In clinics with a high volume of implant surgery and aesthetic smile design procedures, this period can be less than 1 year.
- Added Value: Technological image indirectly increases revenue by improving patient loyalty and "recommendation" rates.

4. Risk Management with an Engineering Approach

As Emin Taner Elmas emphasizes, "unforeseen costs" are significantly reduced because the automation and simulation capabilities of the system minimize production errors. Correct device selection and periodic calibration (mechanical maintenance) extend the life of the investment. [1-64]

Digital dentistry and engineering-based manufacturing systems directly impact a clinic's market position and the cost-effectiveness offered to patients. This competitive advantage can be summarized under four headings: [1-64]

- Pricing Flexibility: By eliminating laboratory costs (courier, technician labor, modeling), the clinic reduces its operational costs. This allows the clinic to offer more competitive prices to patients or use higher-quality materials (e.g., zirconium instead of standard metal porcelain) at the same price level.
- The Monetary Value of Time (Speed): For patients, "time is money." Especially for patients coming from abroad (medical tourism) or those with busy schedules, receiving permanent teeth in 2 hours instead of waiting a week is preferable. This speed allows the clinic to charge a "premium" service fee.
- Reduced Error Rate and Guarantee: Thanks to engineering simulations, the fit of the prostheses produced is close to perfect. This reduces the rate of patients returning for complaints such as "impact" or "falling off" (re-do). The clinic gains confidence in the work it offers, and this confidence provides a significant brand advantage over its competitors.
- Visual Marketing and Persuasion: In the digital workflow, the patient can see the finished result of their teeth on the screen before treatment even begins (Smile Design). This transparent process significantly increases the patient's consent rate for treatment and eliminates hesitations stemming from uncertainty. In short, when the technical precision represented by Emin Taner Elmas is integrated into the clinic, dentistry becomes not just a healthcare service, but a technology center offering high technology. [1-73]

Conclusion

Engineering-based technological transformation has become the most critical factor directly impacting Türkiye's international patient potential by increasing its competitiveness in the health tourism market. The implications of this transformation for health tourism are as follows: [1-73]

- Global Competitive Advantage: Digital dentistry and artificial intelligence integration strengthen Türkiye's position in the health tourism market, enabling the acceptance of over 2.5 million international patients by 2025.
- Speed and Operational Efficiency: CAD/CAM technologies and intraoral scanners drastically shorten treatment processes for patients coming from abroad. For example, prosthetic procedures that traditionally take days can be completed in



1-2 days, allowing patients to both receive treatment and dedicate time to tourist activities.

- **Cost-Effectiveness:** Turkey offers cost advantages ranging from 22% to 50% compared to competitors such as Hungary and Brazil in dental treatments offered using advanced digital technologies. For example, the cost of digital smile design averages \$350 in Türkiye, while it can reach \$2,000 in Toronto.
- **Service Standards and Trust:** Advanced engineering applications such as AI-assisted diagnosis and robot-assisted surgery increase the predictability of treatment outcomes, earning the trust of international patients. These high technological standards position Türkiye not only as a "cheap" destination but also as a "high-quality" one.
- **Integrated Experience:** Clinics combine their technological infrastructure with services such as accommodation, transfers, and city tours, offering an end-to-end digitized patient journey (including telemedicine and AI-assisted monitoring).

Dental health tourism in Türkiye has achieved record growth rates, driven by the engineering-based digital transformation highlighted by Emin Taner Elmas. By 2025, health tourism has become one of the most dynamic sectors of the Turkish economy. [65-72]

Economic Forecasts and Growth Data:

- **Revenue Targets and Achievements:** Turkey increased its revenue from approximately 1.5 million foreign patients in 2024, which was \$3 billion, to even higher levels in 2025. The health tourism revenue target for 2026 is over \$5 billion. [65-72]
- **Share of Dental Tourism:** Dental and aesthetic treatments constitute approximately 50% of the total health tourism volume. The per capita spending of patients coming specifically for implants and aesthetic dentistry reaches between \$5,000 and \$10,000, significantly exceeding the overall tourism average.
- **Global Position:** According to 2025 data, Turkey ranks among the top 5 countries globally in medical tourism. Istanbul, with over 300,000 dental tourists annually, has become the city with the largest dental clinic infrastructure in the world.
- **Annual Growth Momentum:** The share of health tourism revenues in total tourism revenues increased from 5% in 2024 to 6.9% in the first quarter of 2025, signaling strong growth. [65-72]

Economic Outcome of Technological Advantage:

The 60% to 90% cost savings offered to patients from countries like the USA and the UK, combined with engineering marvels

like "Single Session Dentistry" digital solutions, have made Türkiye an indispensable center. [65-72]

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BIOGRAPHY OF AUTHOR:

Asst. Prof. Dr. Dipl.-Ing. Emin Taner ELMAS



Asst.Prof. Dr. Emin Taner ELMAS is a Mechanical Engineer having degrees of B.Sc., M.Sc., Ph.D., and was born in Sivas in 1974. He completed his doctorate at Ege University, Graduate School of Natural and Applied Sciences, Mechanical Engineering Department, Thermodynamics Science Branch, and his master's degree at Dokuz Eylül University, Mechanical Engineering Department, Energy Science Branch. He also completed his undergraduate education at Hacettepe University, ZEF, Mechanical Engineering Department and graduated from the faculty with honors in 1995 and became a mechanical engineer. He was awarded a non-refundable scholarship by the Turkish Chamber of Mechanical Engineers in his 4th year because he was the most successful student during his first 3 classes study at the faculty. He graduated from İzmir Atatürk High School in 1991.

Asst. Prof. Dr. ELMAS has completed his military service as a NATO Officer in Bosnia and Herzegovina. He was a “Reserved Officer” as a “2nd Lieutenant” as an “English-Turkish Interpreter”. He was also a “Guard Commander” and served in Sarajevo, Camp Butmir within the SFOR task force of NATO. He has been awarded with 2 (two) NATO Medals and Turkish Armed Forces Service Certificate of Pride (Bosnia & Herzegovina).

In addition to his academic duties at universities, he has worked as an engineer and manager in various industrial institutions, organizations and companies; He has served as Construction Site Manager, Project Manager, Management Representative, Quality Manager, Production Manager, Energy Manager, CSO-CTO, CBDO, Factory Manager, Deputy General Manager and General Manager.

Asst. Prof. Dr. Elmas is Department Head and is an Assistant Professor of Automotive Technology at the Department of Motor Vehicles and Transportation Technologies at Vocational School of Higher Education for Technical Sciences at IGDİR UNIVERSITY, Turkey. He is also an Assistant Professor of Bioengineering & BioSciences at the same university. He has nearly 30 years of total experience in academia and in industry.



He has served as a scientific referee and panelist for ASME, TUBITAK and many scientific institutions, organizations and universities, including NASA.

He has published numerous international and national academic scientific articles, books, and book chapters, and serves as an editor for international academic journals. He also serves on the scientific committees of many international conferences, publishing conference and congress proceedings and giving presentations.

“Mechanical Engineering, Energy Transfer, Thermodynamics, Fluid Mechanics, Heat Transfer, Higher Mathematics, Evaporation, Heat Pipes, Space Sciences, Automotive, Bioengineering, Medical Engineering Applications, Neuroengineering, Medical Technique” are his academic and scientific fields of study; “Heating-Ventilation Air Conditioning Applications, Pressure Vessels, Heat Exchangers, Energy Efficiency, Steam Boilers, Power Plants, Cogeneration, Water Purification, Water Treatment, Industrial Equipment and Machinery, Welding Manufacturing, Sheet Metal Forming, Machining” are his industrial experience fields.

As of 2026, he has been awarded the Nobel Scientist Award by the international platform organization Scientific Laurels.

Asst. Prof. Dr. Emin Taner ELMAS is also a musician, saz (baglama) virtuoso player and ney (Nay, Turkish Reed Flute) performer. He plays also cümbüş instrument and performs darbuka rhythm instrument. He has a YouTube Music Channel (Emin Taner ELMAS) which includes some of his sound recordings of him playing the saz-baglama and blowing the ney. He composed the poem written by the great poet Âşık Veysel ŞATIROĞLU under the name of “Raşit Bey” in memory of his father Judge (Hâkim) Raşit ELMAS as “Raşit Bey Türküsü”, wrote it down, notated and published it as an academic article and broadcasted this song on his own music channel. He wrote the poems entitled “Canım Babam” and “Geldim Babam” which he wrote also in memory of his father and published in an academic literature journal, and composed instrumental musics for these poems. He also composed an instrumental song called “Annem Annem Türküsü” and gave it to his mother, Lawyer Tuna ELMAS, as a gift on Mother’s Day, 11.05.2025. He also has a poem titled "Ney and Neyzen." He also wrote and presented a poem titled "Esra Kardeşim" to his sister, Esra ELMAS, an archaeologist and English teacher. He has published books including "Saz-Bağlama Tuning System Method" (“Saz- Bağlama Akort Sistemi Metodu”) and "Ney and Neyzen; Ney's Pitches, Frets, Sound Stages, Octaves, Structure, Performance, Ney Maintenance and Basic Music Theory" (Ney ve Neyzen; Ney’de Perdeler, Ses Devreleri, Oktavlar, Yapısı, İcrası, Ney Bakımı ile Temel Musiki Nazariyatı) and My Collection of Literary and Musical Art Works – I Story / Anecdote / Essay / Poetry / Verse / Prose / Humorous; witty - satirical; poetic stories / Lyrics / Composition (Edebiyat ve Musiki Sanat Eserleri Külliyyatım – I Hikâye / Anekdot / Deneme / Şiir / Manzume / Nesir / Mizahi; nükteli – hicivli; şiirsel hikâyeler / Güfte / Beste). He continues his artistic studies by writing various articles, books, poetry, lyrics and also realizing musical composition and repertoire works.