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INNOVATION IN DENTISTRY: A STUDY ON THE DEVELOPMENT OF THE DENTAL IMPLANTS INDUSTRY

INOVAÇÃO NA ODONTOLOGIA: UM ESTUDO SOBRE O DESENVOLVIMENTO DA INDÚSTRIA DE IMPLANTES DENTÁRIOS

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ABSTRACT - Numerous professions face similar technological challenges. In the field of dentistry, specifically, replacing missing teeth has always been a formidable obstacle. Considered a technological benchmark for an entire industry, the osseointegrated implant has spawned not only products and manufacturers, but also an entire economic sector, making it a worthy subject of study. In this paper, we trace the technological evolution of the dental implant from its inception to its commercial viability, including the introduction of the titanium-screwed cylindrical implant, a radical innovation. Through this narrative, we conducted a conceptual review on the topic of innovation, taking into account renowned authors in the field, making this a valuable resource for studies on the subject. We also contributed to the study of technological diffusion proposed by Rogers (1995) by presenting quantitative information regarding the adoption of implant technology by dental surgeons in the state of Espirito Santo. We came to the conclusion that, due to the change in the perspective of functional masticatory reconstruction of patients, the implant was a fundamental innovation for the sector, having always evolved in response to osseointegration as the primary technological pursuit. Beyond the findings, the analysis of the percentage of innovation adoption by professionals during the study period is comparable to the technological adherence curve developed by Rogers (1995). Similar percentages of adherence were observed to those defined by the author, with a small initial group followed by a larger group of later adherents. We restricted ourselves to a quantitative survey and did not investigate the factors that led to or prevented adoption of the new technology.

Keywords: Implants. Innovation. Technology diffusion curve.

RESUMO - Desafios tecnológicos são comuns a diversas profissões. No setor de saúde, especificamente na odontologia, a reposição de dentes perdidos sempre foi um desafio a ser superado. Considerado um marco tecnológico para toda uma indústria, o implante osseintegrado desenvolveu não somente produtos e fabricantes, mas todo um setor da atividade econômica, comprovando assim ser um tema relevante para estudo. Levantamos neste trabalho o histórico do desenvolvimento tecnológico do implante dentário, desde a fase de invenção até sua viabilização comercial, com o surgimento do implante cilíndrico parafusado em titânio, considerado uma inovação radical. Através desta história, fizemos uma revisão conceitual sobre a temática da inovação, considerando autores renomados na área, o que torna este trabalho uma boa fonte de estudos sobre o tema. Contribuímos também com o estudo da difusão tecnológica proposta por Rogers (1995), apresentando quantitativamente, como foi a adoção da tecnologia dos implantes pelos cirurgiões dentistas, tomando como amostra os profissionais registrados no estado do Espírito Santo. Chegamos à conclusão que, em função da mudança provocada na perspectiva da reconstrução funcional mastigatória dos pacientes, o implante foi uma inovação radical para o setor, tendo evoluído seguindo sempre a busca tecnológica principal, a osseointegração. Indo além das descobertas, a análise do percentual de adoção da inovação por parte dos profissionais ao longo do período estudado assemelha-se a curva de adesão tecnológica de Rogers (1995). Encontramos percentuais de adesão semelhantes aos grupos definidos pelo autor, sendo uma pequena quantidade inicial, seguido por um grupo maior de adesões posteriores. Limitamos nosso trabalho ao levantamento quantitativo e não aos motivos que levaram ou não à adesão à nova tecnologia.

Palavras-chave: Implantes. Inovação. Curva de adoção tecnológica.

INTRODUCTION

In Brazil, dentistry has been a regulated profession since 1966 (Law 5081/66). However, historical records of dental care date back to 2500 BCE. (ABRAHAM, 2014). The profession is practiced by the Dental Surgeon, who is required to register with the Regional Council of Dentistry in his state and is subject to the regulations of the Federal Council of Dentistry - CFO (CFO, 2012), which governs his area of professional activity and specialty register.

One of these areas of action is the replacement of missing teeth, a technological challenge that has historically fallen under the purview of the Dental Prosthesis specialty. (CFO, 2002). Dental prostheses, also known as Bridges, Dentures, and Roaches, were the traditional technological foundation of dentistry for many years. (COHEN, 2003). Despite clinically resolving tooth loss and providing relative esthetics, conventional removable prostheses have low retention and little masticatory capacity, whereas fixed prostheses have technical limitations, especially when there is continuous loss of dental elements, in addition to causing a great deal of collateral damage when they are unitary. (VECCHIA, 2009).

These deficiencies stimulated the technological advancement of the dental industry, resulting in the creation of dental implants and the birth of implant dentistry. Attempts to implant human dentition in humans were first documented in Egyptian culture (COHEN, 2003), where implants were first used. It wasn't until much later, after the discovery of the Osseointegration phenomenon, an original factor of more effective and predictable results for patients (CAMPOS, 2012), that the CFO in Brazil began to recognize it as a specialty in 2001.

From that point on, the Brazilian dental implant industry expanded: its production of dental instruments increased by 72%, from $1.6 billion in 2007 to $2.5 billion in 2013. (BARROSO, 2016). In 2017, Brazil had 36 manufacturers of dental implants that produced over 800,000 implants annually, 2.4 million components, and exported to 180 countries. (PENHA Jr., 2017). This results in the development of a production chain for dental implants that includes educational institutions, research centers, producers of complementary inputs such as Biomaterials, machines, and other equipment used by clinicians, dental implant manufacturers, and specialized stores, in addition to dental offices and clinics that serve end users by surgically installing implants. (BARROSO, 2016).

The long history of Implantology has been extensively depicted from a clinical perspective (CAMPOS, 2012; PENHA Jr., 2017; DONATH et al., 2003; FAVERANI, 2011), illustrating the gradual evolution of surgical techniques, materials, and instruments, as well as the manufacturers themselves. The area's bibliography lacks a historical study of this potent industry from an innovation-theoretical perspective.

The research also reveals a deficiency in dentists' assimilation capacity and adoption of implant technology. While some professionals chose to increase their knowledge of the older technology, Dental Prostheses, others opted for the newer technology, implants, much earlier. According to Dosi (1982, 1984), technologies are developed based on particular technical properties, and Schumpeter (1947) adds that the accumulation of experiences and technological knowledge on the part of agents are determining factors for the adoption of technology by a portion of the firm. In addition, the codification of knowledge impedes the adoption of technology because firms differentiate in terms of innovation capacity based on their knowledge base. (DOSI, 1988). Recognizing that some market participants choose early adoption of a new technology, while others choose late adoption (CHRISTENSEN, 1997), it is essential to analyze, in proportional terms, the assimilation capacity of the new technology by the sector professionals who opted for early adoption.

Thus, this work aims to analyze the evolution of the adoption of dental implant technology by dentists, having Rogers' theory of diffusion of innovations (1995) as a reference. As a previous step, a review of the technological evolution of dental implants was carried out under the theoretical lens of innovation. The text was developed in two parts, an initial bibliographic review, where different stages of the technological development of implants were confronted with concepts of innovation and a second stage where, through the quantitative analysis of records of specialists in the CFO.

It is not the objective of this work to describe any surgical technique or to detail materials under a clinical approach. The research was essentially focused on screw-retained titanium dental implants. Thus, other prosthetic components, adjacent biomaterials, advanced surgeries and medications were excluded from the context, even though they are relevant to the dental specialty.

As limitations to the results obtained, it is important to emphasize that the quantitative data were taken from the CFO websites, having as the analyzed population the professionals registered in the council under this specialty. However, a dental surgeon can use the implants even without being registered as a specialist. The justification for continuing the research using this variable is the broad legislation in the area that regulates professional practice (CFO, 2012; CFO, 2020), which can leave professionals who do not qualify as specialists exposed to legal risks, even if this is not illegal, causing the vast majority to choose to register the specialty.

The development of the dental implant industry

Implantology is the specialty whose objective is the fixation in the mandible and/or maxilla of alloplastic materials intended to support single, partial, or removable prostheses and total prostheses, according to the dictionary. (CFO, 2005). Therefore, a dental implant is defined as the use of non-biological materials to support teeth, affixed directly to the bone of the patient.

Implants came to replace tooth-supported prostheses, commonly known as fixed or mucus-supported bridges, commonly referred to as dentures, in terms of the technology employed. (COHEN, 2003; DONATH, 2003). A new technology that improves the patient's swallowing capacity, aesthetics, and durability while preserving biological tissues, particularly bone structure.

Implants have been utilized to replace lacking teeth on numerous occasions. (ABRAHAM, 2014). In an experiment conducted in 1809, gold was first recorded as a material used. Subsequently, other materials were utilized, including Silver, Porcelain, and Iridium Tubes. Few significant results were observed at this stage due to the continual loss of implants due to local inflammation caused by the biological incompatibility of the utilized materials.

There is a period of successive endeavors to develop a viable product during this phase. Using Schumpeter's (1934) definition of innovation as the "introduction of a new product to the market, resulting from an invention or a new combination of resources" as a point of reference, it is currently impossible to classify the implant as an innovation at this stage in its development. Biocompatibility[1] remained a significant technological barrier that prohibited its commercialization as a tooth loss treatment.,

Alvin and Moses Strock partially overcame this technological impediment in the 1930s by adapting orthopedic fasteners for dental use from Cobalt Chromium.

[1] According to Arajo et al. (2022), biocompatibility refers to the capacity of a material to exhibit properties similar to those of tissues and organs, thereby being non-toxic and incapable of inducing toxic events or immunological rejection.

Additionally, other materials emerged and demonstrated some compatibility with biological tissues. The first patent in the field was issued to Adams and his cylindrical stainless steel implant in 1938. (PENHA Jr., 2017).

At this stage in evolution, the Implant satisfies Schumpeter's (1934) definition of innovation, as a product has been developed, as well as Bozeman and Link's concept of innovation. (1984). These authors argue that potential use is necessary to distinguish innovation from invention. The latter is defined as something novel, but devoid of this application.

Under the theoretical frameworks of Fagerberg (et al., 2005) and Kline, Rosenberg, and Landau (1986), it is not yet possible to classify the product as an innovation, despite its existence, because its economic and commercial viability is unknown. Biocompatibility issues render them nonexistent. The product lacks the necessary technical characteristics for commercial viability. The findings of this stage are consistent with the findings of Fagerberg (2005), which state:

> Long delays between invention and innovation may be attributable to the fact that, in many instances, some or all of the commercialization conditions are lacking. There may not be a sufficient demand (yet), or it may be impossible to produce and/or sell, due to the absence of key inputs or complementary factors. (FAGERBERG, 2005)

Other authors, such as OECD (2018), Amabile (2000, p. 332), and West and Farr (1990), do not emphasize the necessity of generating financial results in order to classify something as an innovation. As an illustration, they cite social innovations and process innovations, which are difficult to associate with economic outcomes. In this manner, various theoretical perspectives can be used to designate the precise historical period in which the dental implant appears as an innovation.

The 1960s and 1970s were marked by successive product advancements. Variations in the geometry of the thread and enhancements to the components that connect the dental prosthesis to the implant were validated. In 1963, a novel technology, Dr. Linkow's laminated implant, emerges within this decade. By the end of the 1960s, new materials such as steel and vitreous carbon appeared in Grenoble. Innovations during this period can be categorized as incremental (DOSI, 1988) due to the addition of minor changes and continuous enhancements to the product. There have been consistent and accumulative gains in efficacy over time.

Thus, the evolution of the dental implant is comprised of distinct phases and processes, similar to those of numerous other inventions. In the initial phases of an innovation, crude and unreliable versions are presented, as anticipated (FAGERBERG, 2005), which endure modifications until the products become economically viable. (KLINE, ROSENBERG, LANDAU, 1986).

However, despite the relative success of these materials, a clinical issue remained: many implants were lost after placement. In clinical terms, the patient's bone did not adhere to the implant material, and inflammation developed and the component was lost over time. (PENHA Jr., 2017). This was the "technological concern that shapes the scientific enterprise in many ways" (ROSENBERG, 2006), in this case the search for more biocompatible materials.

In 1952, while researching blood coagulation in rabbits (BRANEMARK, 1959), a physician, Dr. Branemark, unintentionally discovered that when he placed titanium cannulas in their bones, a strong adhesion of the bone to their surface occurred, a phenomenon known as Osseointegration, an essential property for the development of implant technology. (DONATH et al., 2003; FAVERANI, 2011; CAMPOS, 2012). In 1978, the same researcher created his model of Pure titanium cylindrical implants.

Osseintegration was a discovered phenomenon, a technological knowledge that predated scientific knowledge, in accordance with Rosenberg's proposed possibilities for technological development. (2006). This phenomenon is still investigated for a greater understanding even today. (CAMPOS, 2012). The clinician "arrived first, developing potent new technologies before science provided systematic guidance." (ROSEMBERG, 2006).

The development of the cylindrical titanium implant was a revolutionary advancement in implant dentistry in terms of functional and esthetic reconstruction following element loss. Innovations that disrupt existing business models or technologies are characterized as radical. (OECD, 2018). As a result of their impact on the market, "they transform the relationship between consumers and suppliers, restructure economic aspects of the market, destabilize existing products, and create entirely new product categories" (LEIFER, R; O'CONNOR, G.; RICE, M., 2002).

The physician Branemark's discovery about blood coagulation, which resulted in a revolutionary advancement in dentistry, is another important factor to consider. According to Tidd, Bessant, and Pavitt, this and numerous other radical innovations are derived from external industries' technological sources. (1997).

The most significant extant clinical issue was the excessive loss of implants due to local inflammation. In addition to facilitating a simplified and safer operative technique, technological advancements resolved this issue. (CAMPOS, 2012). The establishment of a new technological paradigm (DOSI, 1988) created opportunities for new innovations, clinical techniques, operational processes, and a large industry.

In the 1980s, new incremental innovations were introduced (TIDD et al., 1997), such as the titanium surface treatment, which made it possible to increase the interface's surface area and also included an intramobile element to double the natural teeth's mobility. Technically, the addition of surface treatment increases the implant's osseointegration by increasing its contact area with bone. (ABRAHAM, 2014).

This demonstrates how Rosenberg's (2006) technological need continues to spur incremental innovation. Aesthetics is one of them, a characteristic that is always desired in oral treatments and rehabilitations within dentistry, particularly for anterior teeth. Yttrium-stabilized polycrystalline tetragonal zirconia (ZTP-Y) appears, which also began gaining space as a primary material for dental materials, beginning to be used in the production of dental implants due to its biocompatibility, mechanical properties, and, most importantly, aesthetics. (FREITAS et al., 2017; FERNANDES et al., 2020).

The diffusion of innovation and the dental implant industry

Implants are placed in patients by dentists, who must be certified to do so. A dental clinic must possess a set of technological capabilities for the implant industry to develop. It is unrestricted interdependence (DOSI, 1988) that connects one economic activity to another, facilitating the flow of products and services and the sharing of experiences and opportunities.

Technological capacity "(...) consists of the resources required to generate and manage technological changes. Such resources (such as talents, knowledge, and experience) accumulate and are incorporated into individuals and organizational systems. (BELL; PAVITT, 1993). Thus, the technology existed, but it was also necessary to create a diffusion network for its future consumers. An implant cannot be purchased by the end user like a cell phone, but is used during a clinical procedure by a qualified dentist to reconstruct the patient's masticatory system. It is a novel technology for this actor, which necessitates further technological capacity development.

Biosafety, clinical planning, correct selection of the implant, systemic health of the patient, examination analysis, post-surgical follow-up, in addition to operative conditions, influence the level of success in the use of dental implants. (MARTINS et al., 2011). Therefore, for the dentist to utilize dental implants, Technological Capability must be developed.

In 2001, the CFO registered the specialty. (CFO, 2012). The Industry's partnership with training centers and colleges was a significant step towards the dissemination of technology. (APCD, 2020). In 2001, following the recognition of the specialty, specialization courses were registered, giving the professional greater legal protection when adopting the technology. This partnership between research institutions and national industry even resulted in the registration of a patent for the micro implant with a drill, an innovation developed in Brazil, by the Faculty of Dentistry of Ribeiro Preto (FORP) of the University of So Paulo (USP).

This emergence of national technology is consistent with the findings of Figueiredo (2011), who discovered a greater level of innovation in multinational industries with a more developed local relationship network, knowledge exchanges, and an emphasis on quality improvement.

> Subsidiaries have the potential to integrate into various kinds of knowledge networks in order to amass the capabilities required for

> innovation in products, production processes, and services, thereby bolstering their competitive position. (FIGUEIREDO, 2011)

The expansion of specialization courses has brought the academy closer to the clinics, continuing its dissemination, and even creating opportunities for the technological recovery of laggards (FIGUEIREDO, 2019), i.e., professionals who had not yet adopted implants as a treatment option but did so as the technology became more established. This reality refers to Lee and Malerba's (2017) study when they discuss the various responses of market participants to a new technology. Rogers (1995) explains this variation in participants' responses to the adoption of a new technology in his theory of innovation diffusion, the process by which system members adopt an idea, product, or service.

According to the author, the degree of innovation, communication channels, social networks, and the perceived risk associated with innovation can all influence the diffusion of innovations. (BAUER et al., 2018). The success of an innovation's diffusion depends on how swiftly and effectively its intended audience adopts the idea, product, or service. Relevant factors include communication channels, social media usage, and the degree of risk associated with it. (REID; REID, 1997). In order to increase the adoption rate of their product or service, companies can also use the diffusion of innovations to develop more effective marketing strategies, such as targeted advertising campaigns. (CHEN; CHEN, 2019).

Rogers' (1995) Technology Diffusion Curve attempts to explain how new technologies become integrated into daily life. It proposes that the adoption of a new technology follows the behavioral pattern of the five groups that exist in society: the innovators par excellence, the early adopters, the first innovative majority, the late majority, and the latecomers. The author also asserts that the process of adopting a new technology is complex, involving multiple factors such as price, usability, resource availability, community adoption, and peer pressure, among others. The percentage distribution of participants by group is depicted in Figure 1.

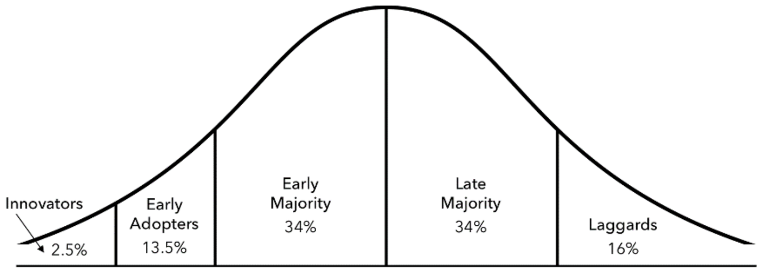

Figure 1: Rogers Diffusion Curve
Source: Rogers (1995)

Exemplary innovators are those who implement the technology first and account for 2.5% of the participants. They are the most inclined to experiment with new technologies and take risks. They are typically visionaries and innovators rather than trend-driven decision makers. In addition, they frequently have ample financial resources and can cover the initial adoption expenses.

Then there are the early adopters, who utilize the technology a bit later than the pioneers (13.5 percent of the population). They are innovators, but they are less risk-tolerant than early adopters. They have a positive impact on the community and can help spread technology. The first innovative majority consists of 34% of respondents who adopt the technology after it has been popularized by pioneers and early adopters. They are conservative and prudent in their decision-making and will implement technology more slowly.

Similarly, 34% of respondents are those who implement the technology only after it has become well-established. They are typically very cautious and will implement technology even more slowly. 16% of the population, the laggards, acquire the technology long after it has become prevalent. They are typically resistant to change and the implementation of new technologies.

METHODOLOGY

For the analysis of dentists' adoption of dental implant technology, registration documents with the Regional Council of Dentistry of the State of Esprito Santo - CRO/ES were examined. Population data from specialist registrations were collected.

They are public knowledge and the result of consultations with the aforementioned council. The same information is available on the CFO website; however, as the purpose of the work is to analyze the trajectory of adherence to the specialty, the CFO website does not list the professionals who adhere to it year by year.

Due to the prompt transmission of information by this section of the CFO, we chose to conduct a single case study, as waiting for responses from the other sections would have delayed the completion of the research. Future research will compare the researched state to the other states in search of exogenous variables that interfere with the process of technology adoption, such as macroeconomic aspects of the region.

From 2001 to 2022, the number of records pertaining to implant dentistry specialists was compiled annually. This variable was chosen to represent the professional's adherence to technology. It is common knowledge that in order to register a specialty, postgraduate courses must be registered with the CFO. Each course requires a minimum of 1,500 hours of labor over a period of two to three years. (CFO, 2002). It should also be noted that registration as a specialist is not automatic upon completion of the course; rather, it is the professional's choice. Consequently, there may be a delay between completing the course and becoming a specialist.

It is essential to analyze this context, as a professional is not required to register as a specialist in order to utilize the technology. Thus, there may have been a period of time between the introduction of dental implants and the registration of the specialty, which is the subject of this study. Nevertheless, this variable was selected because it represents official data and the entire population. Due to the difficulty of obtaining contact information for professionals and other confidential data, sampling would be another form of registration. Microsoft Excel was used to analyze the collected data statistically.

Initially, a descriptive statistical analysis was conducted to determine the characteristics of the population under study. Next, the number of practitioners registered annually in the CRO/ES was verified, with comparisons made to the

Implant Dentistry specialty. Finally, the research area's technological adherence curve was contrasted with Rogers' curve. (1995).

RESULTS

There are 7,714 registered professionals in the state of Esprito Santo, and 5,580 new professionals were registered with the CRO/ES between 2001 and 2023. There were 505 enrollments specifically for implant dentistry specialists, representing 11% of the total number of new enrollments during the period. Figure 2 depicts, on a yearly basis, the proportion of professionals who adhere to the specialty in comparison to the total number of enrollments.

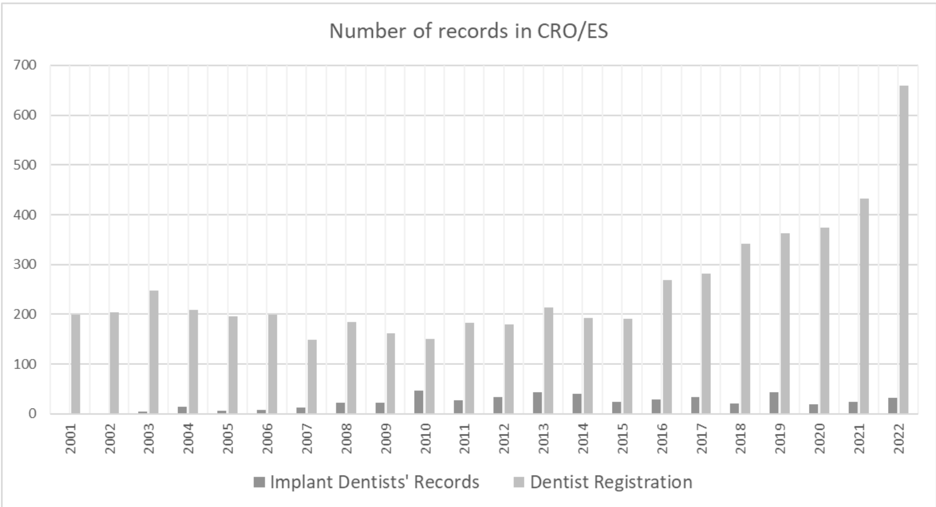

Figure 2: Comparison between records of new dentists and specialists in implant dentistry
Source: CFO (2022) and CRO/ES (2022)

This graph demonstrates that new technology adopters grew proportionally until 2010 and that the continuous growth in the number of professional registrations, especially since 2015, has not been accompanied by an increase in the number of implant dentistry specialists.

Taking a deeper look at the relationship between newly registered professionals and new technology adopters, Figure 3 reveals a low initial adherence that steadily increases, followed by a decline in the area's demand. Since the specialty record captured by this study does not precisely reflect the beginning of technology use, it was decided to record the percentage of adhesion in the graph as a moving average of the three previous years, maximum time required to complete the specialization course in the area.

Two factors support the conclusion. One is the lack of control over the precise date of course completion and the use of technology. The professional who completes the course has no deadline for registering the specialty, and the fact that he did so in a given year does not indicate that he concluded the course and began using the technology in that exact year. The second objective is to reduce graphic distortion and level out year-to-year variations.

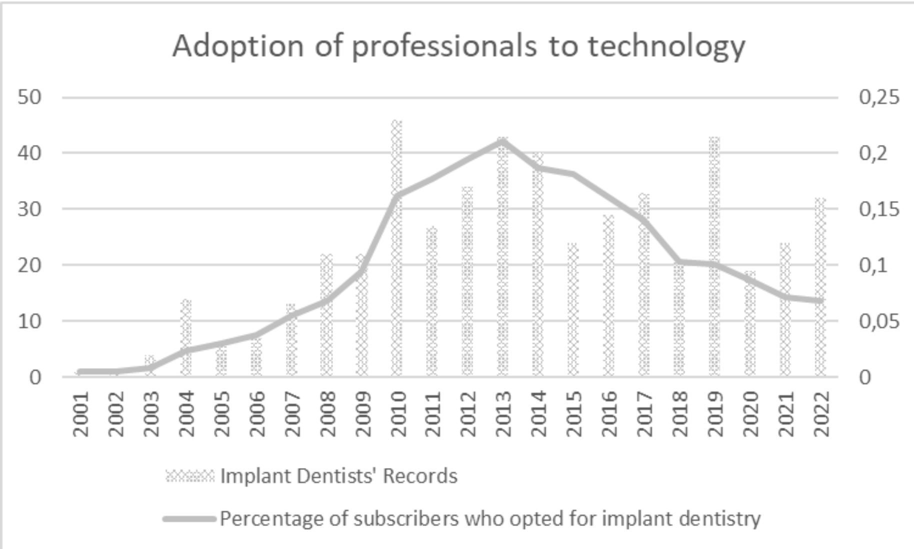

Figure 3: Quantitative and percentage of adoption to the new technology in the state of ES
Source: CFO (2022) and CRO/ES (2022)

Although the figure does not precisely depict a curve, one can see through the line a similarity between the proportion of professionals who adopted the technology of dental implants and the Rogers (1995) presented technological diffusion curve in Figure 1. In Table 1, the percentages of technology adoption from the performed analysis are contrasted to those proposed by Rogers. (1995). Despite the fact that the values are not identical, it appears that the groups have numerical similarities.

Membership comparison table		
Groups	Percentage according to Rogers (1995)	percentage found
Innovators	2,50%	3,90%
Adopters	13,50%	13,99%
Initial majority	34%	37,60%
Late majority	34%	33,50%
Laggards	16%	11,08%

Table 1: Comparison between the adherence percentage of implant dentists in ES and that expected by Rogers (1995)
Source: CRO/ES (2022); Rogers (1995)

This variation is depicted in greater detail in Figure 4, which includes the percentages found within the adherence categories proposed by Rogers (1995).

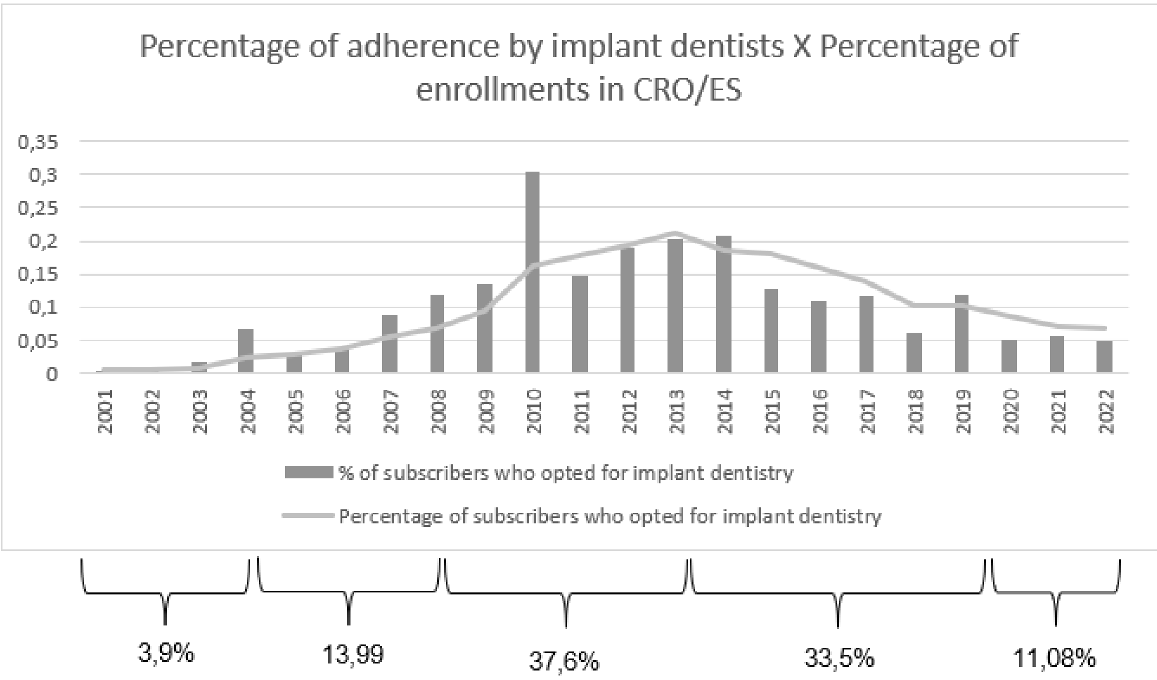

Figure 4: Percentage of adherence by implant dentists, compared to the percentage of new enrollments in CRO/ES
Source: CFO (2022) and CRO/ES (2022)

Although it does not precisely match the numbers proposed by Rogers (1995), the rate of adherence to the technology observed in the chosen sample exhibits similarities with the theoretical model, such as a moderate initial adherence, followed by growth, and then a period of time when the majority of the group joins.

FINAL CONSIDERATIONS

The purpose of this paper was to provide a concise overview of the evolution of the dental implant industry in relation to its consolidation as a new technology for the dentistry industry. Further, the technological adherence of professionals from the state of Esprito Santo was analyzed using Rogers' (1995) technological adherence curve as a theoretical guide.

It is concluded that the osseointegrated dental implant was a revolutionary innovation (LEIFER et al., 2002) for the entire dental industry and that, over the course of its development trajectory, it exhibited various incremental innovations. (TIDD et. al., 1997). The evolution of the product validates established theories regarding innovation, such as Kline, Rosenberg, and Landau's (1986) assertion that innovations endure changes from the time they are introduced until they become economically viable.

Branemark's (1959) technological achievement of osseointegration, pursued by the industry at the time, was merely the result of the technological concern that influenced the industry, as described by Rosenberg. (2006). A network of interdependent economic activities developed around the innovation (DOSI, 1988), which contributed to its diffusion, citing as an example the courses required for the certification of professionals who adopted the technology.

In this manner, a contribution to the conceptual study of innovation was made through an unprecedented historical analysis of a significant sector of the nation's economy.

Limitations of the study included the selection of a single state for evaluation and the need for a more precise comprehension of when the professional begins to use implant technology. To put it another way, additional research should be conducted to determine when the professional begins using the technology, given that we use their registration with the class council as a benchmark. This may occur, for instance, during your training course.

In addition, it is suggested that other states be included in the research and that exogenous variables, such as local macroeconomic factors, be incorporated in order to verify exogenous effects that impede adherence to innovation in the sector.

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