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VALUE GENERATION IN THE SUPPLY CHAIN OF DENTISTRY PRODUCTS

Jeren KURNAZ

Master's Thesis

Supervisor

Asst. Prof. Dr. Fatih YİĞİT

İstanbul, 2024

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The thesis titled VALUE GENERATION IN THE SUPPLY CHAIN OF DENTISTRY PRODUCTS prepared by JEREN KURNAZ and submitted on 12.7.2024 has been **accepted unanimously** votes for the degree of Master of Science in Industrial Engineering.

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I hereby declare that this thesis meets all format and submission requirements for a Master's thesis.

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Jeren KURNAZ

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DEDICATION

I would like to thank all Altınbaş University professors who taught us and Asst. Prof. Dr. Fatih Yigit who guided and supported me during my thesis work.

ABSTRACT

VALUE GENERATION IN THE SUPPLY CHAIN OF DENTISTRY PRODUCTS

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As people began to pay more attention to their health, the importance placed on dental health and aesthetic appearance began to increase rapidly. During the research, we saw that dental ceramics are the most important product which helps this increase.

Dental ceramics have become indispensable products in the modern dental world. To increase the quality of the finished tooth manufacturers, distributors, technicians, and dentists worked on innovations for almost 100 years. With the increase of new technologies and innovative products, the value of the finished work also increased rapidly. In today's world dental health become a very expensive procedure for everyone in the world. It is important to learn the main parameters that effects the value of the finished artificial tooth by evaluating it value chain. To understand the value chain of dental ceramics SD Ceram Dental Ceramic Brands information’s are used.

The value chain of dental ceramics starts from the manufacturing of powder forms and finishes with the transformation of powders into artificial teeth. The theoretical calculations show that the price of the finished tooth does not change from region and city. Real market price changes not because of the outer forces but because of the price flexibility for the word done by dentists and technicians. In this thesis, we find out that the reason of increase of finished artificial tooth is because of the uncontrolled pricing for the work done by technicians and dentists. To solve this problem some governmental controls regarding the

pricing of the work done by dentists and technicians can be done to solve the high pricing problem of the dental market.

Keywords: Dental Porcelain Ceramics, Value Chain Analysis, Distribution Channels, Pricing Strategies, CAD/CAM Technology.

ÖZET

DİŞ HEKİMLİĞİ ÜRÜNLERİNİN TEDARİK ZİNCİRİ DEĞERİ

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İnsanlar sağlıklarına daha fazla dikkat etmeye başladıkça diş sağlığına ve estetik görünüme verilen önem de hızla artmaya başladı. Araştırma sırasında bu artışa yardımcı olan en önemli ürünün diş seramikleri olduğunu gördük.

Diş seramikleri modern diş dünyasının vazgeçilmez ürünleri haline gelmiştir. Bitmiş dişin kalitesini artırmak için üreticiler, distribütörler, teknisyenler ve diş hekimleri neredeyse 100 yıldır yenilikler üzerinde çalıştı. Yeni teknolojilerin ve yenilikçi ürünlerin artmasıyla birlikte, biten işin değeri de hızla arttı. Günümüz dünyasında diş sağlığı herkes için oldukça pahalı bir işlem haline gelmiştir. Bitmiş yapay dişin değer zincirini değerlendirerek değerini etkileyen ana parametrelerin öğrenilmesi önemlidir. Dental seramiklerin değer zincirini anlamak için SD Ceram Dental Ceramic Markanın bilgileri kullanıldı.

Diş seramiğinin değer zinciri, toz formların üretiminden başlar ve tozların yapay dişlere dönüştürülmesiyle tamamlanır. Teorik hesaplamalar bitmiş dişin fiyatının bölgeye ve şehre göre değişmediğini göstermektedir. Gerçek piyasa fiyatı dış etkenler nedeniyle değil, diş hekimleri ve teknisyenlerin söylediği fiyat esnekliği nedeniyle değişmektedir. Bu tezimizde bitmiş yapay dişlerin artmasının sebebinin teknisyen ve diş hekimlerinin yaptıkları işin kontrolsüz fiyatlandırılmasından kaynaklandığını tespit ettik. Bu sorunu çözmek için diş hekimleri ve teknisyenler tarafından yapılan işlerin fiyatlandırılmasına ilişkin bazı hükümet kontrolleri yapılabilir ve bu şekilde diş hekimliği pazarındaki yüksek fiyatlandırma sorunu çözülebilir.

Anahtar Kelimeler: Dental Porselen Seramikler, Değer Zinciri Analizi, Dağıtım Kanalları, Fiyatlandırma Stratejileri, CAD/CAM Teknolojisi.

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ABBREVIATIONS

AI	:	Artificial Intelligence
UTS	:	Product Tracing System
CAD/CAM	:	Computer Aided Design/Computer Aided Manufacturing
EMA	:	Regulatory bodies like the European Medicine Agency
FDA	:	U.S. The Food Drug Administration
ISO	:	International Organization for Standardization
DSD	:	The Digital Smile Design
MDR	:	Medical Device Regulations
MDD	:	Medical Device Directives
MEDDEV	:	Medical Devices Documents

LIST OF SYMBOLS

^{o}C : Temperature

1. INTRODUCTION

In the modern world, the importance given to dental care has increased. One of the most popular reasons is people start to pay more attention to their appearance. Many people experience tooth loss. To avoid this situation, people started to take care of their teeth. However, after tooth loss, people started to look for a real dental appearance and old functionality of their teeth. In the world of modern dentistry, technicians who can respond to this quest have begun to increase their skills and opportunities. Manufacturers have started to produce new technologies to improve the quality of technicians' tooth-making process and find out how to shorten the time of this process. A search has begun for a product that gives the most natural appearance to replace lost teeth. We can say that dental ceramics are the most suitable material in terms of usage diversity, color, transparency, and durability in dental prostheses. Technicians also constantly improve themselves by improving their mastery to create a masterpiece from dental ceramics sold in different forms, creating artificial teeth in the human mouth that are no different from other teeth. For years, the common goal of manufacturers, dentists, and technicians has been to work on how to obtain the most natural-looking teeth in the highest quality and fastest way.

In this thesis, I aim to provide a deep perspective on the world of dental ceramics, to determine the final theoretical price offered to the consumer. We evaluated the content of dental ceramics, their production, distribution channels, and the value added by the technician during product processing. Our aim is not only to determine the value chain but also to determine how this process may change in the future and how it can be improved over time.

Background: The story of modern dentistry starts with the needs and expectations of patients regarding dental care. This process has also brought about the development of technology in this field. Thanks to the increase in global population and the great focus on keeping teeth healthy, the demand for dental prosthetics has increased. This increase in demand has motivated dental technicians and manufacturers to increase the quality of their products to have a great look and function of the final product. Creating dental prosthetics, especially those made from porcelain ceramics, is the best well-known product regarding quality, great look, and function. It is not just about filling the gaps left by missing teeth, but about

processing every fine detail of the natural dental appearance. A dental technician's most comprehensive work starts with choosing the right colour and materials and finishing with placing those materials accordingly until they become teeth. A dental technician's comprehensive work starts with choosing the right colour and materials and finishing with placing those materials accordingly until they become teeth. This process involves everything from getting the materials ready to modelling and finally delivering them. In today’s dentistry world, there’s a shift towards creating prosthetics that don’t just look like natural teeth but also work like them. There is tight competition between dental technicians to create the most natural teeth and do it in the shortest period. During these processes, the properties of the materials used together with the technical infrastructure also gain importance. The most favourable product in this field is dental porcelain ceramics. These products give the look and function of our original teeth. They become essential in achieving the best outcomes for oral health. That is why it is very important to understand how dental porcelain ceramics go through this detailed process. It is very important to make sure that finished products meet the highest standards and quality.

1.1 HISTORICAL OVERVIEW

As to the history of dental prosthetics, we can see the change in societal attitudes toward oral health changed throughout the years. History takes us to the old centuries when animal teeth were used to replace dental prosthetics. The milestone for dental restoration started in the 18th century. During this period innovative work of ceramists laid the foundation stone for dental ceramics. The transformation of porcelain ceramics to dental ceramics was a revolution, it changed the understanding of dentistry. Material and technique improvement started in the late 19th and early 20th century. During this period the improvement in dental ceramic formulations and firing technologies played a big role. As a result, of the first usage of porcelain-fused-to-metal (PFM) crowns and bridges started in dental prosthetics. After that, the technological improvement in this field continued to develop. The demand for aesthetical appearance and durable teeth remained central. The relationship between forms and functions becomes the future of restorative dentistry. Porcelain ceramics play a big role in dental restorations which give a natural look.

1.2 TECHNOLOHICAL BACKGROUND

The late 20th century was a revolution from a technological point of view in dentistry. During the thesis period significant improvement was made in terms of material science and manufacturing techniques. Improvement in material substructure is the most important approach to the quality and durability of teeth, which are made from dental ceramics. In this period different types of approaches in the process of preparation of dental prosthetics started to be used.

The innovations were not only aimed at the aesthetical appearance but also technological developments were targeted. The result is not only a natural look but also durable and strong teeth. Technological development also helps technicians to prepare teeth in a short period with the same quality and look. These technologies have been developed over time and are now widely used in design and manufacturing processes. Computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies are the most known and popular technologies in the new dental ceramic world. These technologies are known as CAD/CAM Technologies. With the help of these technologies, more accurate measurements and advanced time preparation of dental prostheses became possible in comparison with labour-intensive methods.

Recently, the development of various dental porcelain formulas has led to many technological innovations. Zirconia and lithium disilicate are considered to be a few of the most important among these formulations. Developing new formulas and technologies has opened new horizons for dentists and technicians. This is a new learning area for dental professionals, and with this knowledge, they have gained the ability to make teeth that are personalized for the patient and as durable as natural ones.

1.3 MARKET DYNAMICS

We know that the interest in dental restorations increases with the increase in sensitivity towards special oral health. The market for dental restoration has increased dramatically in the last century. The popularity of the dental restoration market has increased especially because of the need for an esthetical look and biocompatibility. It also comes with the increase in a preference for minimally invasive treatment.

The development of the dental restoration market has not only affected the spread of the understanding of dental health but also led to significant changes in terms of economic considerations. With the increase in challenge for high-quality and technological investments, manufacturers, technicians, and dentists, the cost for each value chain step is increased dramatically. At the same time, all players try to maintain cost-effectiveness to keep market dynamics. Thanks to this balance, the implementation of reimbursement policies has begun in many countries. This has led to competition among key players in this value chain. The development of competitive strategies in the dental industry has also affected the development of innovations. With the help of these strategies, it has become easier to provide high-quality dental prosthetics in the rapidly developing market. The flow of information between all stakeholders in the value chain has become easier with the improvement of technology, leading manufacturers to implement pinpoint strategies in product development.

1.4 REGULATORY LANDSCAPE

With the increase in demand for dental ceramics, strict regulatory guides started to be implemented in most countries. The priority was patient safety, effectiveness, and quality of the products. Regulatory bodies like the European Medicine Agency (EMA) and the U.S. Food Drug Administration (FDA) played a big role in the implementation of related standards for all dental materials, especially for dental ceramics. Dental ceramics started to be evaluated as medical devices (risk class IIa). ISO 13485 Quality Management System for Medical Devices was forced to be implemented for all value chain players. CE (Conformity European) certification rules started to be implemented. This requires different testing and documentation at every stage of the production process. As well, product performance is forced to be analysed during manufacturing processes. It is forbidden to use dental ceramics in the market which do not meet regulatory conditions. It is very important for manufacturers and all role players to follow all regulatory guides. The aim is to ensure that the finished product, which is the teeth that will be implemented in the human mouth, are made from dental ceramics that meet the highest standards of biocompatibility, durability, and overall safety. Other value chain players also need to implement ISO 13485 regulatory requirements. So, starting from the choosing of raw materials and finishing with the

implementation of finished teeth into the human mouth, there are very strict rules in terms of a regulatory point of view.

1.5 EMERGING TRENDS

The global trend of dental restoration is moving towards personalized dentistry and minimally invasive treatments. New advancements are found in digital density with the increase in innovative technological products. Also, some new materials started to play an important role in dental prosthetics preparations. It seems to be the emerging trend for dental ceramics

Another important trend is 3D printing technologies, which help to make 3D measurements of the teeth directly from the human mouth. This technology helps to customize prosthetics and increase of usage of prosthetics in the same comfort as natural teeth. With this measurement, very little detail of human teeth can be measured and copied.

At the same time, researchers found some new biomimetic materials that can stand for dental ceramics.

Also, machine technologies with AI (Artificial intelligence) will play a very important role in the value chain of dental ceramics. This kind of technology will help with planning, material selection, and process optimization. In the future dentists also can be able to use AI-based technologies to improve the treatment time and to minimize the cost.

These emerging trends may lead to a new transformation in the dental restoration world. With the gradual development of technologies, dentists and technicians are expected to improve themselves very quickly to keep up with the fast-developing world. These speed trends will become the compass of the future for them.

1.6 CHALLENGES AND OPPORTUNITIES

If we evaluate each player in the dental ceramics value chain we can see that each one has challenges and opportunities. But the main goal for all of them is to have the most natural and durable teeth.

The challenge starts with the quality of important raw materials. Unfortunately, it is very hard to find manufacturers who can produce all active materials every time with the same

purity. Afterward, it is very important to have a thermal expansion and breakdown point for the products. During the tooth preparation as an infrastructure, some different materials are used. The main challenge is to produce a product that will have a thermal expansion that is suitable for all possible infrastructure. It is a very big opportunity for manufacturers who can decrease the thermal expansion of their dental ceramics, since with this low thermal expansion result their products can be used with the newest technological innovations which started to be used in metal infrastructure.

The second challenge is color match for dental ceramics. For manufacturers, it is very important to have very different colored dental ceramics forms. The coloring should be done according to the Vita color scale. Distributors and technicians' challenge is to get the right colors. Everyone's teeth have a different color, so the challenge is to predict the right ones. The opportunity for distributors and technicians is, if they can analyze very well the market needs they can utilize the stock value and have all demanded products. For the dentist, the challenge is to determine correctly the color that best suits the patient's tooth color and convey it to the technicians with the correct measurement. Since this part is the start of the demand it is very important to have the right colored teeth to have satisfied patients. The opportunity in this field is to have innovative AI technologies that can give the right color and measurement for personal needs.

2. LITERATURE REVIEW

The literature review is done for the main topic 'Value Chain of Dental Porcelain Ceramics.' It is found that there is no direct research done regarding this topic. As an alternative keyword 'value chain' is looked for between 2018-2024 publications. Only 3 articles can be used for this research. One of them is written in “Global Value Chain Mapping.” Written by Frederick [1]. The second is written by Johnson [2] in the article "Measuring Global Value Chains.". The last one is written in the article ‘Measuring what Matters in Global Chains and Value-Added Trades" written by Borin and Mancini [3]. All of them give important knowledge about the global value chain. In the article written by Frederick, the global value chain mapping system is evaluated. According to their research, the value chain mapping for all types of markets starts with the Research and Development stages, proceeding with Manufacturing and Distribution strategies, and finishing with Marketing and Supporting Service Stages. In the first stage product development steps are done. At the end of this step, the value of the product will be determined. In the second stage, there is purchasing, manufacturing, testing, batch release, and logistic steps are evaluated. The last stage is the Marketing and Supportive Service. There are education, marketing expenses, and service expenses as the main steps. There are also evaluated different types of approaches used in value chain implementations. But the closest to our value chain is the GVC (Global Value Chain) approach. In the other two articles which were written by Johnson and Bornin the different calculation approaches for GVC calculations are evaluated. Unfortunately, there is no direct calculation formulation evaluated in this article related to import and export plus the global value chain of dental ceramic

To understand the value of dental ceramics the articles with the keyword 'dental ceramics' are researched. There are many different articles written during 2018-2024. Most of them are related to the evaluation of the clinical side of view. However, we evaluated one article which can be used in this research. One of them is written by De Matos [4] in the article 'Dental Ceramics: Fabrication Methods and Aesthetic Characterization'. In this article, the fabrication method and the teeth preparation steps are evaluated. This article shows the main important steps in the value chain of dental ceramics. According to the article, ceramics are classified into three main groups: glass-matrix ceramic, polycrystalline, and hybrid ceramics. There are different fabrication methods, indications, and characterization layers

that can be used in each ceramic group. In our research, we will evaluate the glass-ceramic group value chain.

The technique of tooth preparation is shown in the following Figure below (Figure 2.1, Figure 2.2, Figure 2.3, Figure 2.4, Figure 2.5, Figure 2.6):

Figure 2.1: Modeling [4].

Figure 2.2: Shaping the Model's Mold With Wax [4].

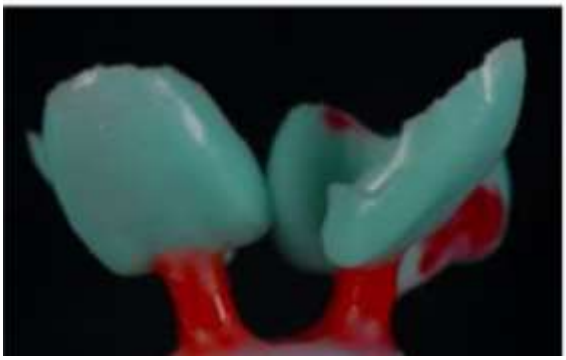


Figure 2.3: Preparation the Wax For Dental Ceramic Stage [4].

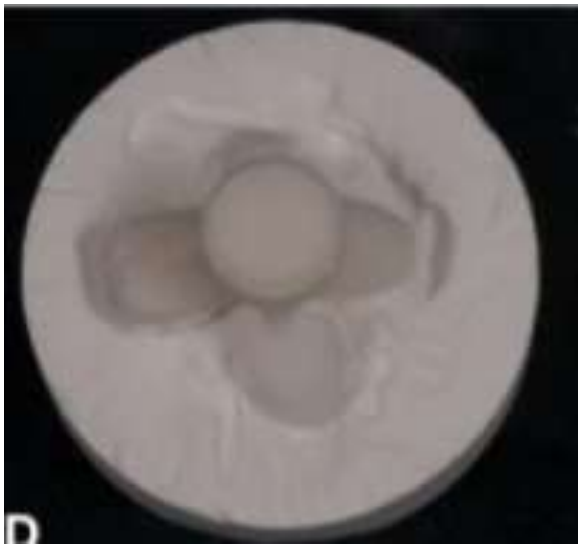


Figure 2.4: Firing Stage of Dental Ceramics [4].

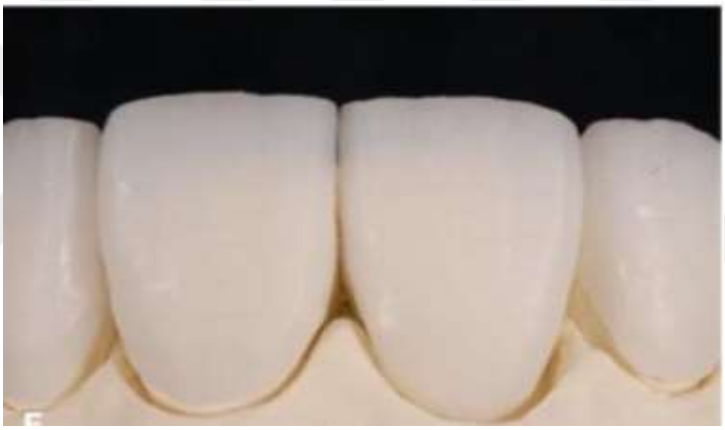


Figure 2.5: Before Glazing [4].

Figure 2.6: The Artificial Tooth After Glazing [4].

Artificial tooth preparation using CAD/CAM Milling technique is shown in the figures below (Figure 2.7, Figure 2.8, Figure 2.9)

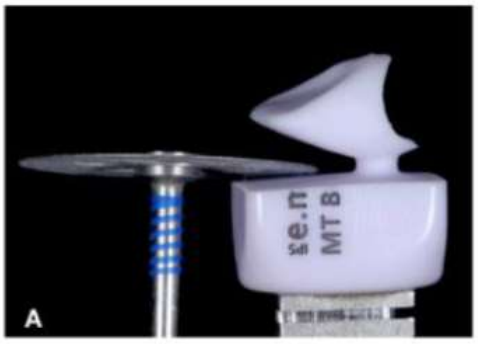


Figure 2.7: Cutting Out Milling Model from CAD/CAM [4].

Figure 2.8: The Model Shape After Crystallization [4].

Figure 2.9: The Model Shape After Stain Technique [4].

2.1 INTRODUCTION TO DENTAL PORCELAIN CERAMICS

There are different types of ceramics in the world. In this research, we will evaluate the information grading dental ceramics, which is produced according to the glass-ceramics production process. The main information regarding production processes is evaluated in the research paper 'Dental Ceramics: Fabrication Methods and Aesthetic Characterization'. De Matos et al., “Dental Ceramics.” [3]. The main ingredients in dental glass-ceramic products are silica, feldspar, alumina, and some other inorganic chemicals in very small amounts. The difference in the percentage of each ingredient gives the quality of basic products but the difference in pigmentation processes gives a variety of colouring scales.

In the late 19th century lithium disilicate started to be used as an additional main ingredient in dental ceramics. With the foundation of this formula, manufacturers added new forms to their portfolios. This new innovative product become a revolution in dental ceramics. According to one article, there is one more star product that will make a revolution in the dental ceramic market, which is zirconia. In the research named 'Current Status on Lithium Disilicate and Zirconia.' Written by Zarone et al. [5]. Zarone evaluated the new generation of particle-filled and high-strength ceramics, hybrid composites, and techno polymers in his research. We found out that there was an increase in the demand for non-metallic infrastructure for dental ceramic teeth. Therefore, Zarone gives more attention to products like lithium disilicate and zirconia which work as the main part of the teeth and infrastructure at the same time. During this research authors' clinical experience and scientific literature researched are used. He found out that the main properties of these products are their optical and aesthetic properties, together with high biocompatibility, high mechanical resistance, and reduced thickness. In many in vitro and in vivo studies these results are pointed and because of these properties clinicians and technicians started to use these products actively.

In today's word, the formulations for zirconia and colouring form of lithium disilicate are used speedily. At the same time to use of these products' technological innovations also increased with the CAD/CAM technologies and different types of ovens which can be used easily for light distillate forms. The application of such metal-free ceramics has become more and more prevalent over time.

2.1.1 Composition of Dental Porcelain Ceramics

Dental glass-ceramics mainly consist of silica, feldspar, alumina, and other glass additives which are mainly inorganic chemicals. There is much research written regarding the composition of dental ceramics and their function. We chose the newest one where ingredients and technological research are done in the same article. Solis Pinargote wrote an article titled 'Materials and Methods for All-Ceramic Dental Restorations Using Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) Technologies—A Brief Review'. [6]

One of the main ingredients is Silica, which is a main component in dental ceramic composition. This chemical contributes to the structural integrity of dental ceramics. The main role of this chemical is to maintain the material's stability and enhance resistance to wear. The second important material is feldspar. This chemical has a unique mineral composition, it adds both strength and translucency to the ceramic material. This chemical mostly influences the esthetic view of teeth and also influences the mechanical properties of ceramic products. Another important material is alumina. This chemical contributes to the overall strength and hardness of dental ceramics. This chemical enables teeth to meet their current daily functional needs.

Additionally, according to Zarone et al. [5], and Solís Pinargote et al. [6], in new forms of dental ceramics lithium disilicate has become the newest important ingredient. This chemical gives high translucency and robust mechanical properties. It introduces a balance between aesthetics and strength.

Both authors also gave important attention to Zirconia dental ceramics. This product consists of Zirconium dioxide, which is tougher, more durable, and less prone to break. Zirconia products are in block-shaped forms.

2.1.2 Mechanical Characteristics

The main mechanical characteristics of dental ceramics are ensuring the longevity and functionality of the finished prosthetics. A study conducted by Ceddia, Lamberti, Trendatue, and colleagues [7], gives us information on flexural strength, the relationship between composition, processing techniques, and other abilities of the ceramic materials. In this study

mechanical properties of three different types of materials are evaluated; ceramics, enamel, and zirconia. They used 3D modeling and numerical analyses to understand how each material affects the stress distribution, with respect to natural teeth. As a result, it shows that ceramics have lower resistance to usual stress than zirconia materials. But in terms of esthetical characterization ceramics are more excellent than zirconia. It clearly shows that the toughness of selected materials directly affects stress distribution in restored teeth. The applied pressure also plays an important role in the transmitted stress. The application of a horizontal load increased stress on the surface of the zirconia crown with respect to the ceramic crown. It shows that ceramic crown has lower sensitivity in the direction of applied force. During this measurement, the layer between the crown and dental layer is not considered because the aim was to evaluate the stress response of the surface of the tooth.

Another article was written by Vallerini et al, [8] evaluated the mechanical properties of lithium disilicate. During testing almost 50 experimental lithium disilicate-based glass ceramic compositions are used. Their glass-forming ability and the effect of various heat treatments on their crystallized fraction, crystal size, and morphology, a particular formulation was selected to optimize the mechanical properties of the material. The samples were treated in different temperature phases. The starting temperature is 500 ^{0}C, the second phase is 700 ^{0}C and the last is 840 C. In the last phase, a lithium phosphate seemed to precipitate. The research different techniques used to measure mechanical properties. For elastic modulus impulse excitation technique (ASTM E 1876-15) is used. By indentation and piston-onthree balls test (ISO 6872) technique Hardness and Flexural strength are measured. As a result of the study, it was found that lithium disilicate products have almost the same properties as commercial dental glass ceramics [7].

This study shows the influence of crystallized fraction and crystal morphology in shaping the mechanical properties of materials used in oral restoration. The clinical performance of dental ceramics is affected by their mechanical properties. Hardness shows material resistance to indentation and scratching, it also influences the material's ability to maintain its structural integrity over time. Where wear resistance, shows the material's ability to withstand the force encountered in the mouth.

2.2 EVOLUTION OF DENTAL PORCELAIN CERAMICS

The dental Ceramic field has undergone more revolution than evolution in the last century. It has renewed the dental ceramics market, especially with the inventions made in the last 30 years. As the awareness of research and inventions increased, people began to understand to what extent people could improve their dental health. At the same time clinic professionals also started to increase their ability of treatment to respond to the needs of patients with the help of research done in this field. In the article written by Shah et al., “The 100 Most Cited Publications on Dental Ceramics between 1980 to 2020.” [9] the calculation index is considered an important parameter for measuring relevance in the dental ceramic field. These articles can provide basic information and recent advances. The most citations were received by the article 'Bio ceramics: From Concept to Clinic' which was written in 1991. In this article author described 'the extensive use of Bio ceramics which may be bioinert, bioactive resorbable, or porous material for tissue connections. Herein, the author also highlighted that the use of Bio ceramics is not just limited to dentistry but can also be used for the repair of damaged tissue, orthopaedic surgeries as well as the replacement of maxillofacial and periodontal structures.'

The second-highest-cited article is 'State of the Art of Zirconia for Dental Application'. In this article, the properties of Zirconia are evaluated. Three different types of Zirconia used in dentistry are evaluated. The author discussed Zirconia's varied applications and its mechanical and aesthetic properties.

In Shah's research, it is seen that there has been a tremendous amount of revolution in manufacturing processes and the application of dental ceramics.

2.3 TECHNOLOGICAL ADVANCEMENTS IN DENTAL CERAMICS

One of the revolutions in the dental market came with the foundation of Zirnconia-based ceramics. The form of Zirconia is produced by pressing technology. The shape is in round block form. After some in vitro and in vivo studies were conducted manufacturers of dental ceramics improved themselves in the field of Zirconium Block production. To use these blocks by technicians they need to use technology since it is nearly impossible to make prosthetic shapes from blocks by hand. With this need, CAD/CAD (Computer-aided design and manufacturing) technology comes into use. In the research of Solis Pinargote et al.

2024., with the article ‘Materials and Methods for All-Ceramic Dental Restorations Using Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) Technologies—A Brief Review' the latest materials used in ceramic dental restorations and production methods are evaluated. According to the article, with the decrease in demand for metal substructures in dental ceramics the research for alternative substructures that will satisfy esthetical and functional needs. After what zirconia-based ceramics come our. With this new production process contribution to the technological advancements in CAD/CAM technologies started to be implemented by dentists and technicians. It enables exacting planning, and enable the creating of customized prosthetics that will be prepared for each patient. [9]

In the article, it is very clearly informed about how CAD/CAM technologies are used. Prosthetics are usually milled from a single Zirconia block by using CAD/CAM technology. Since one block is used for the whole mouth, the colour of teeth also will be the same. This color-matching needs force manufacturers to make innovations in the formulation of Zirconium block production which will answer to the need for any colour and dimension. In the last 3 years, Multilayer blocks also started to be produced. With the development of the formulations CAD/CAM technologies also played a crucial role in the preparation of strong and durable restorations that look exactly like natural teeth. With the increase of this technology digital 3D scanners also started to be used widely. With the help of this scanner, 3-dimensional models of the oral cavity and teeth can be measured accurately. These technologies reduce the number of steps in the prosthetic teeth preparation processes, which consist of design, creation, and implementation. It also reduces manufacturing time and increases the accuracy and quality of the final product. It is very important to take accurate measurements of the human mouth since a small difference can cause huge discomfort. This technology also helps to create dental substructures with complex shapes and designs. Since the materials in Zirconia blocks are similar to dental ceramics. To get a more natural view porcelain ceramics are used as a structure component.

2.4 LASER GLAZING IN DENTAL CERAMICS

There is also a laser application technique on porcelain ceramics during the preparation of dental prostheses. In the study of Ibrahim Abdallah, [10], in the article named ‘Exploring

Laser Glazing Interaction with Dental Ceramics: A Comprehensive Study' the interaction between laser glazing and dental ceramics is observed. Laser glazing helps to utilize the surface of teeth, and gives an esthetical view and mechanical properties of dental ceramics.

In the laser glazing process, laser energy is used on the ceramic surface to melt it. This process can change the microstructure and surface topography of the ceramics. It helps to improve the mechanical properties, wear resistance and gives esthetics. Unfortunately, the effectiveness of laser glazing depends on laser parameters, ceramic composition, and glazing techniques.

All three types of dental ceramic composition are evaluated in this study: zirconia-based ceramics, glass-ceramics, and lithium disilicate-based ceramics. At the same time to utilize glazing processes, different parameters were used like wavelength, power, scanning speed, and spot size to see the effects of glazing outcome. The surface of dental ceramics is examined before and after laser glazing, via two different microscopes. Also, mechanical testing was done for dental ceramic products before and after laser glazing to see the effect on hardness, flexural strength, and wear resistance. For aesthetical view change the evaluation was done by dental professionals.

The result of the study for surface characterization shows that in all types of dental ceramics, the surface becomes more homogenous and the porosity, and roughness of the surface seems to be reduced. It is also found that mechanical properties are also improved after laser glazing. Between tested compositions, zirconia-based dental ceramics show the highest improvement. As the last aesthetic test glass dental ceramics and lithium disilicate dental ceramics show very effective results. The improvement of translucency and the view of natural teeth was increased significantly.

2.5 MARKET TRENDS AND DEMANDS OF DENTAL CERAMICS

Literature research was done with the keywords 'market trends and demand for dental ceramics' unfortunately there is no direct article regarding this subject. However, some information was received from social media, manufacturers, and technicians. They also approved that they have witnessed the changes in dental ceramic market trends. Even in the last three years, the demand for dental ceramic-based tooth restoration products has

increased dramatically. This increase in demand forced the market trend to shift to technological evolution. Some Turkish ceramic manufacturers tried to produce dental ceramics but the composition of the finished product did not meet the needed quality. Technicians started to use different technologies to make perfect teeth in a very short time. All players in this market started to improve themselves to keep up with the pace of the market. With a decrease in demand for metal-based substructures zirconia and lithium disilicate products also some to the Turkish market. Dentists and technicians started to use CAD/CAM technologies for Zirconia-based dental ceramics blocks. Thanks to this technology, the number of teeth they make daily has increased to almost 5 kst. Thus, costs were optimized and we started to keep up with the new trend. The information we have obtained matches the development of the Turkish market trend with the information and developments we have obtained from our separate literature reviews above. The only difference is that this development in Turkey has increased much faster than in many other countries in the last 5 years.

2.6 DIGITAL WORKFLOW IN DENTISTRY

Digital workflow in density has increased due to the technological evolution which increases the quality of work. Workflow in dentistry starts from the manufacturing process of the main basic materials. However, the most important workflow starts from the measurement of the cavity of a patient who needs dental restoration. The help of intraoral 3D scanners and software programs helps to communicate between the clinical and dental technicians. One example of this kind of software is The Digital Smile Design (DSD). This tool helps to prepare rehabilitative aesthetic planning to get the expected outcome for the treatment. This kind of program help also to simplify the documentation process and optimize the work process.

In the research study of Stanley et al, [11], the case study was evaluated. In this study fully digital workflow was experienced. In this study firstly 2D photos taken from different parts of the patient transformed via CAD software to 3D models. Then 3D printers are used to get the intended model. After the model was taken the bite test was performed to see if there was any discomfort in the patient's mouth. After approval of the feet of the 3D-printed model crown from the dental ceramic started to be used. Lithium disilicate or Zirconia blocks are

preferable to use in the substructure of the crown. From 3D scans using CAD/CAM technologies crowns can be printed directly without a human hand. However, it is also possible to add some stain layers on the prepared crown to have more natural teeth. The final product was put in the patient's mouth. After 6 months of follow-up, it was determined that the new teeth were conformal and did not cause any pain.

The photos regarding the case study are also evaluated and listed below:

Figure 2.10: Picture of Problematic Teeth [11].

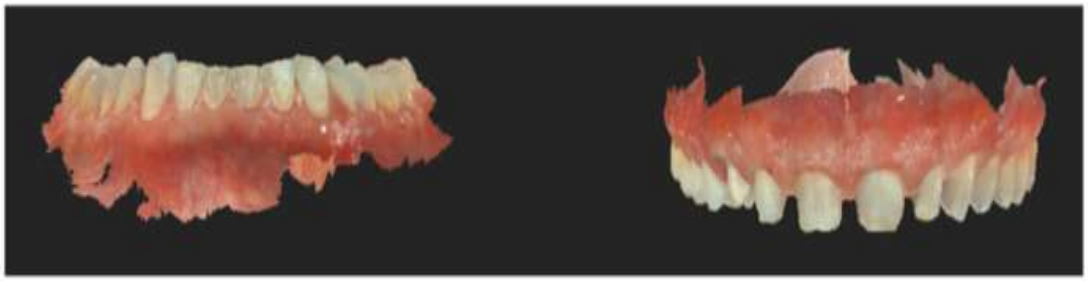


Figure 2.11: 3D Scan of The Teeth. [11].

Figure 2.12: Corrected 3D Scan Version [11].

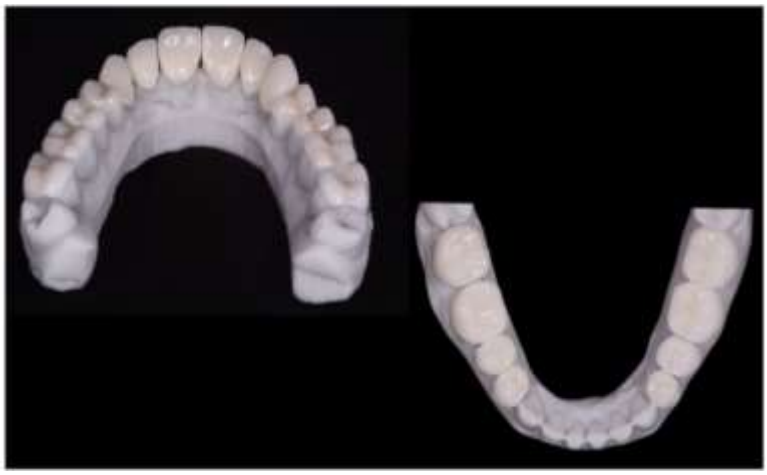


Figure 2.13: 3D Printed Version [11].

Figure 2.14: The Last View of The Crown in The Mouth [11].

2.7 REGULATORY LANDSCAPE AND QUALITY STANDARDS IN DENTAL CERAMICS

During the literature review, no article was found regarding dental ceramics regulatory and quality standards of dental ceramic products. However, there is much ISO and MEDDEV documentation regarding the medical device regulations and quality aspects of dental ceramic products. MDR (Medical Device Regulation) and MEDDEV documents provide not only the information but they become the main compass and guide for manufacturers to get quality products that comply with regulatory requirements and launch them on the market. Before 2021 MDD (Medical Device Directives) was used compulsorily. After MDR came into force not only manufacturers but also all participants of the value chain of dental

ceramics started to comply with all relevant rules. Starting from manufacturers, proceeding with distributors and technician laboratories, and finishing with the dentist all these participants need to have ISO 13485 (medical device quality management system) certification and they have to comply with the rule to use in their work only products which have CE marking on it.

CE marking products means this is a medical device. MDR has a rule where you need to read if your product is a medical device or not. There are different types of classes for medical devices. Which are classified according to the risk they can cause to the patient. The first aim of these regulations is to ensure human health. Cass 1 is divided into 3 groups. Class I, Class I sterile and İnvasive medical devices. Class II is divided into two groups such as Cass IIa and Class IIb. Class III is the last class. Products that are implanted in the human body are directly classified in this part. There are many different rules for each type of class. Dental ceramic products are evaluated as class II-a medical devices. According to MDR for this class of products Clinical evaluations and post-marketing Research should be done to watch if there will be any side effects that comes from the dental ceramics or not.

2.8 EMERGING TRENDS AND FUTURE PROSPECTS

Personalized dentistry has become a very popular point in the dental market. With the increase in the demand for dental ceramic prosthetics and natural views, the work of each participant in the value chain increased dramatically. This forces everyone to optimize their workforce and to prepare the finished product at one time with maximum correctness. To answer these needs technological innovations started to race to get the product which will help to get more precise results. Since demand in the value chain starts based on the patient's needs, the first and most important step is to correctly identify the problems and needs of the human mouth. Technologies like X-rays and 3D scanners function for this. X-rays used for many years biomedical engineers worked on the improvement of X-ray technologies that will give less damage and the most correct print of all detail problems of the patient's mouth. But for 3D scanners and 3D printers, machines become indispensable products. There are many different types of cameras and other different technologies used in this machine to get very precise measurements of each cavity of the needed place. D. Nesic in its article with the name of '3D Printing Approach in Dentistry' [12], evaluated the importance of 3D

printers in personalized dentistry. In this article, 3D printing technology allows to production of any 3D objects based on the chosen material. Digital technological developments done in these spheres have futures like the production of surgical guides, educational models, and the biological reconstructions of periodontal tissues from laboratory to clinical case. According to this research, we found out that there are many types of 3D printing in the world. The 3D technology that includes cells has been named 'bioprinting' and the hydrogels, in which cells reside for printing purposes, have been named 'bionics'. 'The main advantage of extrusion bioprinting is the possibility to use multiple materials and cell types in different combinations. Laser-assisted bioprinting (LAB) is based on a laser pulse that produces local heating of a cell-containing solution

There are more than 139 publications in 3D printing in the dental field. The history starts with first digital image-getting machines, then Intraoral-scanning techniques innovated which help to transfer images to 3D printers. Now there are so many scanning techniques used in the world. One of them is computerized tomography, another is cone beam computer tomography and magnetic resonance imaging, and the last one is laser digitizing with extraoral or intraoral scanning devices. After scanning the oral cavity data should be processed to the software modelling technology, like CAD (computer-aided design). With the help of this software, the scanned image transfers to the 3D printer, and the model will be successfully taken. In the dental market, 3D printers are successfully used in prosthodontics, orthodontics, orthognathic, endodontics, craniofacial, and oral and maxillofacial.

2.9 ARTIFICIAL INTELLIGENCE IN TREATMENT PLANNING: SHAPING THE FUTURE OF DENTISTRY

Artificial intelligence (AI) is the process of training a computer until it starts to think like human beings. There are very much literature regarding AI technologies, which explains how AI will help to optimize heavy processes. We will evaluate the research done by Bonny et al., in the article “Contemporary Role and Applications of Artificial Intelligence in Dentistry.” [13]. Bonny explained in his research how AI plays a role in the dental market. AI provides essential help to automate different activities, like the assessment of radiographic images to detect a dental disease more accurately and faster. AI can calculate from different data the exact measure from different pictures and model it correctly by using

digital workflow technologies. The future of AI in dentistry will be used to determine the right treatment and then to get an excellent model. It will work as an assistant for the dentist and technicians. It can notify the dentist throughout the process of creating a digital imprint and assist in excellent work. It can optimize the final scan by eliminating the unwanted frames during scanning and developing a restoration design that replaces the anatomy of the lost tooth structure. It can decrease human error in the finished prosthetics. Even if numerous studies are showing the potential application of AI in dentistry, these systems do not seem to be able to replace completely dental professionals. AI surely will be an additional benefit for dentists and technicians, but it should be implemented in a controlled manner in a workflow.

3. METHODOLOGY

3.1 PORCELAIN CERAMIC FORMS AND WELL-KNOWN BRANDS

There are many dental ceramic manufactured forms in the market under different brands. In this thesis glass ceramics forms are evaluated. The most used form is powder form. These forms are the first released ones in the market. Porcelain glass ceramics are prepared by heating the chemical mixtures to 1500 ^{0}C degrees, turning them into a homogeneous glass, and then breaking it into powder. In this way, the master mixture of the relevant layers is prepared. These mixtures are mixed with pigments at a ratio of 1/100 to obtain colored powders suitable for the Vita scales. These colored powders are sold in bottles of various sizes. These powders are used by technicians by mixing them with the relevant liquid before use.

Later, products containing lithium disilicate began to be introduced to the market. The marketed form of this product is tablet form. 3 g and 2 g powder forms are compressed and shaped into a homogeneous tablet by keeping it in the oven at 700 °C for 1 minute. These tablets are melted into wax molds created by technicians in furnaces specially designed for lithium disilicate products and turned directly into teeth. No liquid mixture is used for this product.

The newest form of dental ceramic products that is frequently used is the paste form. This form is preferred to be used by technicians, especially in the upper layers when making teeth. Technicians use this product directly on the teeth with a brush in the desired amount. This form ensures optimal use of the time and materials spent on tooth production, especially for its aesthetic appearance.

A) Ingot

B) Structure

C) Powder and Liquid

Figure 3.1: Forms of Dental Ceramics [14].

Three well-known Brands that dominate the Turkish dental ceramic market are EVOCLAR, GS, and SD Ceram. There are also some national brands but the quality of other brands is not the same as these well-known ones. In the selection of these brands factors like market share, product diversity, and reputation are evaluated. All these brands have almost the same colors and labels with various layers of tooth preparation like dentin, enamel, mamelon, clear, opaque, and stain. In tooth preparation dentin becomes a foundation, enamel becomes a canvas, mamelon is used for intricate detailing, clear is used for transparency, opaques are used as concealment, and stain is used for the final brushstroke.

In this thesis, one of the main well-known brands SD Ceram will be used during the evaluation of the value chain of dental ceramics. The owner of this brand is a global Asfarma company. This local player operates not only as a manufacturer but also main distributor which works directly with technicians. They also distribute all the products that are used by technicians during tooth preparation. That is why they play a very important role in the value chain dynamics.

3.2 STRUCTURE OF DENTAL CERAMICS

SD Ceram porcelain ceramics are physically released in;

i. Powder form, in jars containing the specified amount,

ii. Paste form within the 3 and 5 gr jars, and

iii. Tablet forms that contain lithium disilicate.

The material group is alumina silicate glass ceramic (Al2O3SiO2). Main components connected to glass-ceramic structure: SiO2, Al2O3, K2O, Na2O, CaO, B2O3. There are different product groups and colors for all types of dental ceramics:

Dental ceramic products groups that are used on metal:

i. OPAQUE POWDER: Provides covering on metal.

ii. OPAQUE DENTIN: Increases opacity in dentin.

iii. DENTIN: Imitates the natural transparency of enamel.

iv. ENEMAL: Imitates the pearl transparency of enamel.

v. TRANSLUCENT: Creates special enamel pigments.

vi. CHROMA: Provides color intensity.

vii. MAMELON: It creates natural color fluctuations in the dentin.

viii. GINGIVA: In gingival recession losses, it imitates the gum to eliminate the losses and to provide its aesthetic appearance.

ix. GLAZE: Porcelain glazes on the surface

x. SHADES: Tints in the finished glazing.

Dental ceramics has a wide range of different color types which are used to correct the colors of all its veneers and mimic every possible natural tooth color characteristic:

Gingiva: whenever it is necessary to compensate for the missing gingival tissue in the pontic or cervical area of restoration, different Gingiva powders can be used.

Enamel, Clear/Neutral, Opal, Opal Enamel, Transparent /Transparent light/Transpa T, Mamelon/Smart Mamelon, BL, and Flu are mainly used in the enamel part of a restoration to achieve special color effects during the enamel part of the restoration.

Base, Cuspid, and Fosse are special color powders that expand the possibilities of technicians by following special veneering techniques inspired by famous dental technicians and porcelain artists.

All advanced coating powders need to be baked in the first or subsequent Dentin cooking program.

Cooking:

After dentin application, the crown is placed in the baking tray at an initial temperature of 450°C.

The oven is then closed with a drying time of 6 minutes and heated to 920°C by vacuum (vacuum starts at 450°C) to 920°C per minute (cooking temperature). Standby time: vacuum for 1 minute.

When the first dentin/enamel cooking is complete, straighten and clean the edges of the crown or bridge. Then, apply a second Dentin and enamel coating for the second Dentin cooking to achieve the final restoration shape and compensate for the sintering narrowing.

For second cooking follow the procedure in the first Dentin cooking with a cooking temperature of 920°C. Any additional Dentin cooking should be done at a temperature of 915°C.

If necessary, apply Opaque Dentin powders in specific colors (neutral, yellow, orange, brown), Chroma Modifier in different color tones (A, B, C, D), or Dentin Modifier powders in certain colors (white, yellow, orange, brown, pink, purple, blue) to obtain different colors in the restoration body coatings.

Glaze Coating / Glaze Baking:

After covering the surface with a diamond tool, deeply clean the crown or bridge.

Cooking:

Deeply clean the frame and sheet with steam or water and a brush before proceeding to another porcelain application.

Place the crown in the baking tray at an initial temperature of 450°C. Then, turn off the oven for 3 minutes and heat vacuum-free to between 50°C and 910°C (cooking temperature) per minute. Standby time: 1 minute without vacuum.

Dental ceramic products groups used on Zirconia substructure:

i. OPAQUE DENTIN: Increases opacity in dentin.

ii. DENTIN: Imitates the natural transparency of enamel.

iii. ENAMEL: Imitates the pearl transparency of enamel.

iv. TRANSLUCENT: Creates special enamel pigments.

v. CHROMA: Provides color intensity.

vi. MAMELON: It creates natural color fluctuations in the dentin.

vii. GINGIVA: In gingival recession losses, it imitates the gum to eliminate the losses and to provide its aesthetic appearance.

viii. GLAZE: Porcelain glazes on the surface

ix. SHADES: Tints color in the finished glazing.

Each porcelain ceramics group has also a wide range of different color powders which are used to correct the colors of all its veneers and mimic every possible natural tooth color characteristic:

Gingiva: whenever it is necessary to compensate for the missing gingival tissue in the cervical area of restoration, different Gingiva powders can be used.

Enamel, Clear/Neutral, Opal, Opal Enamel, Transparent /Transparent light/Transpa T, Mamelon/Smart Mamelon, BL, and Flu are mainly used in the enamel part of a restoration to achieve special color effects during the enamel part of the restoration.

Base, Cuspid, and Fosse are special color powders that expand technicians' possibilities by following special veneer techniques inspired by renowned dental technicians and porcelain artists.

All advanced coating powders need to be baked in the first or subsequent Dentin cooking program.

Cooking:

After dentin application, the crown is placed on a baking sheet and placed in the oven at an initial temperature of 450° C.

After that, the oven is kept closed for 6 minutes and heated to 810°C by vacuum (vacuum starting temperature: 450°C) to 45°C/min. Holding time: vacuum for 1 minute For multiple dentures with a large amount of porcelain, the cooking temperature can be increased by approximately 10°C.

After the first Dentin/Enamel cooking is complete, shave and clean the crown or bridge. Apply a second Dentin and Enamel coat to cook the second Dentin at the end. For second cooking all programs are the same just the temperature decreases to 10 C.

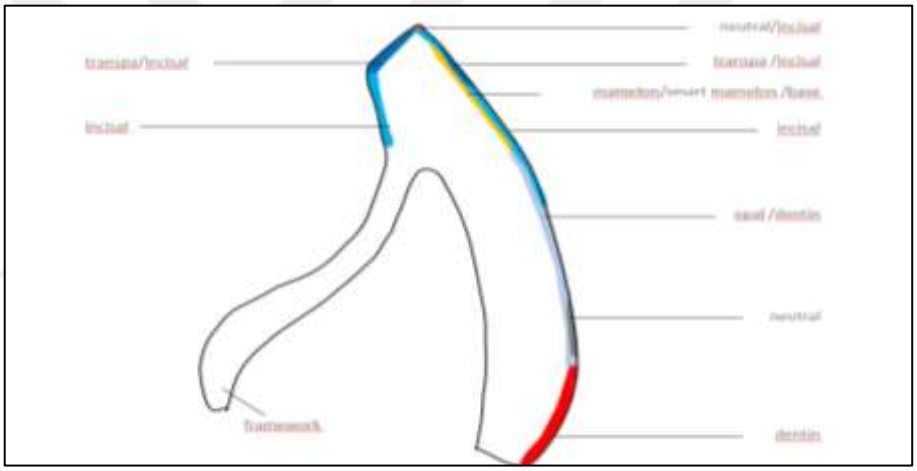


Figure 3.2: Layers of Dental Ceramics in Tooth Preparation.

3.3 ESTHETIC CONSIDERATIONS IN DENTAL PORCELAIN CERAMICS

No matter what the infrastructure is, the teeth prepared by the technician must look like natural teeth. For this, the ingredients of the selected product, the technical specifications of the product, and colour harmony are very important. First, the infrastructure is prepared according to the tooth shape obtained from the 3d scanner. If the infrastructure is metal, it is made opaque so that the metal shine will not be seen. The dentin layer is first coated on the metal and baked at the appropriate temperature. It is important to choose the colour of the

dentin layer according to the patient's other teeth. It is baked after other layers are applied sequentially to the dentin. Finally, stain powder layers are applied to give transparency to the tips of the teeth. After all the firing is completed, the teeth are shaped by the technicians with diamond-coated burs to give the line of natural teeth. Thus, it becomes almost impossible to distinguish the artificial tooth from the real tooth.

Figure 3.3: Esthetic Considerations in Dental Porcelain Ceramics [14].

3.4 TURKISH PRODUCT TRACING SYSTEM (UTS)

In Turkey, all medical devices and cosmetic products should be registered in the Turkish tracing system (UTS). The role of UTS is to ensure the traceability of each medical device and cosmetic product that is imported or produced for the Turkish market. Each serial number of each product is being followed in this system. Class I products can be registered in this system by the declaration of conformity. However, all other medical device products should be registered with their CE certificates. All dental ceramic products are specified as medical devices class II-a.

Not only is the registration ensured with the UTS system but also the supply chain of the product is also controlled. If the products are imported the registration is done by distributors with manufacturers CE certificate. The information regarding imported goods is entered by distributors. If distributors sell goods to technicians directly they inform them as consumers in the UTS system. If they sell them to dealers they also should be registered as customers and ensure traceability.

The role of distributors and dealers is to inform the government through the UTS system about each imported batch of each product. If any registered product is produced in Turkey, manufacturers should inform each product of the released batch of each product through the UTS system.

3.5 TECHNICIANS' ROLES IN THE SUPPLY CHAIN

Supply chain tracking from the UTS system finishes at the technician's site. Technicians use different colors and different products during the preparation of one finished tooth. During the preparation of one tooth, almost 3 gr of dental ceramic is used. The information regarding the shape of the tooth comes from the dentists through the 3D scanning system. This 3D scanning system specifies color scale and tooth dimensions which are needed by dentists. Technicians use 3D printers to prepare models and then use manual techniques to prepare teeth.

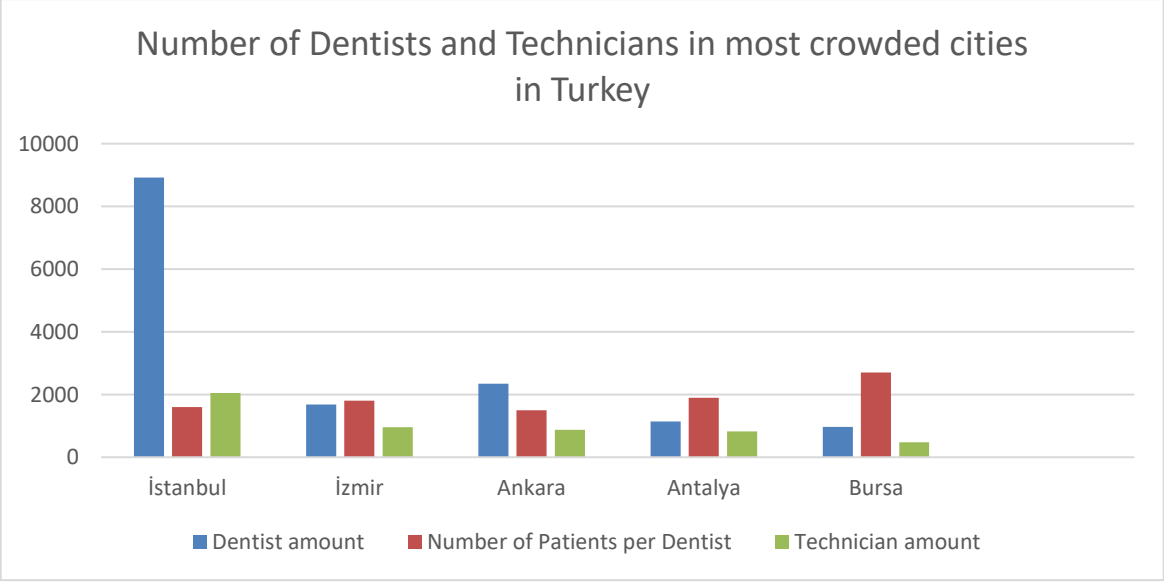
Dentists role in supply chain: The dentist's role is the starting point in the value and supply chain. The process begins with dentists determining the dental needs of patients. It starts with the decision that an artificial tooth should be made on an implant or as a bridge. A 3D scan is made for the needed tooth and the required color is selected and sent to the technician. Doctors can also decide on the material to be used depending on the patient's needs

4. CALCULATION AND RESULTS

4.1 CALCULATION

The main purpose of this thesis is to evaluate the value chain of porcelain ceramic starting from manufacturing bulk price and finishing with the price of the tooth that the patient will pay. The calculation will be done according to theoretical calculations. The result will be compared with the original tooth price that dentists now give for one dental ceramic tooth. For price evaluation SD Ceram brand is used. The main players in this calculation will be wholesalers, technicians, and dentists' approximate expenses. To evaluate the expenses different location variations in Turkey were taken into consideration. The aim is to see if the location has an important impact on the price change of the finished product or not. During the selection of places most crowded population and approximate needs of the population are taken into consideration. In Graphic 1 the selected most crowded cities in Turkey and the number of dentists and technicians in these cities are examined. These numbers help us to choose the most crowded city. The crowded city was chosen because there is high competition between distributors, technicians, and dentists.

Chart 4.1: Number of Dentists and Technicians in Most Crowded Cities in Turkey.



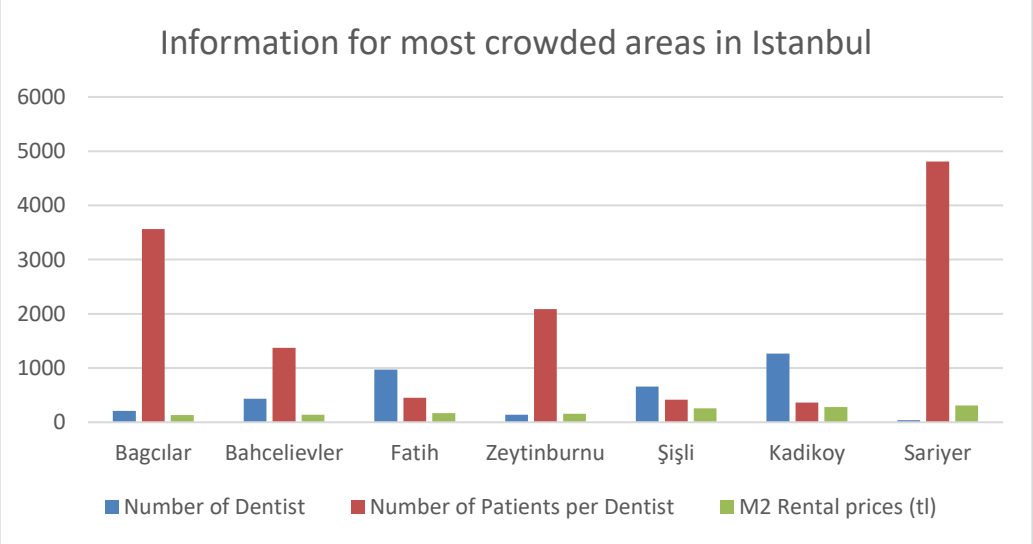
According to Graphic 1, we can see that there is a significantly high number of dentists in Istanbul and there is also a high amount of population in Istanbul. The highest number of dentists shows the highest potential work volume and also shows the demand rate. That is why Istanbul is chosen for further calculation.

The next step is to find the strategic region within Istanbul. This selection is important to us because, in the real market, the price of a dentist for one finished tooth is different according to the region. Therefore, when choosing the area, the m2 rent costs of the relevant shaded area were taken into consideration. Because the largest variable item of a business is known as rent.

Table 4.1: Information for Most Crowded Areas in Istanbul [15].

Regions	Number of Dentists	Number of Patients per Dentist	M2 Rental prices (TRY)
Bagcılar	212	3564	133
Bahcelievler	433	1372	139
Fatih	973	449	170
Zeytinburnu	138	2088	157
Şişli	659	416	256
Kadikoy	1267	362	283
Sariyer	39	4811	309

Chart 4.2: The Most Crowded Areas in Istanbul.



When choosing the region, we considered not only the rental prices but also the competitiveness in the relevant region. The regions with the most technicians, the most patients and the most dentists were selected. Since the number of doctors and technicians is low in the region the number of patients is relatively low and the number of patients is high, prices can be easily minimized by dentists and technicians depending on the income ratio of the patients.

According to Table 4.2, we can evaluate some similar regions and calculate the theoretical expense of one tooth for each selected region. We will make further evaluations for Bagcilar, Fatih, and Kadikoy regions.

Table 4.2: Price Calculation for the Dental Ceramic Tooth in Selected Regions in Istanbul.

Region	Potential Number of teeth in one month	The sum of expenses and salary	Porcelain Ceramic Cost for 1 tooth	The theoretical price for one tooth for a technician (TRY)	The theoretical price for one tooth (TRY)
Bagcilar	99	36650	38	613	1475
Fatih	112	38500	38	571	1370
Kadikoy	110	44150	38	659	1591

When calculating the potential number of teeth, a dentist could do per month, it was calculated by dividing the total number of patients per dentist by 36. Here, the possibility that a patient would need at least one tooth replacement at least every 3 years was considered.

The following method was used when calculating expenses in selected regions:

i. An average area of 50 m2 was selected as the operating area for rent expenses. The m^2 price in the region is multiplied by 1.50.

ii. 30000 TL was calculated as gross salary expense. Considered a dentist's office or a technician's work area.

When calculating the cost of the powder used by a technician to make a tooth, the wholesaler's selling price is taken as a basis. 100 grams of dental ceramic products are sold for approximately 1300 TL. It is assumed that an average of 3 grams is used to make one tooth.

At this stage of the value chain, the most important factor that determines the price of dental ceramic material, which serves as raw material for the technician, is the price positioning of competing brands. Global brands such as EVOCLAR and GS have positioned the same price almost in all countries. Although the SD Ceram brand is of the same quality, it sells at a very affordable price in order to take the market shares of rival brands. Since the raw material producer of the SD Ceram brand is a European company, the purchasing cost is in euros, but it has to work with a profit margin of at least 50% due to having to keep a wide variety of stocks.

In order to calculate the theoretical cost for the technician tooth price, the potential number of teeth in a month, the cost of dental ceramics that can be spent on a tooth, and other monthly expenses are added. The resulting figure is divided by the average number of potential teeth. By adding 50% profit to this cost, the theoretical price of the tooth extracted by the technician was calculated.

When calculating dentists' costs for a tooth, the following method was used; Monthly costs were divided by the average number of patients, and the cost of the technician per tooth was added. By adding 50% profit to the overall cost, the theoretically calculate the cost of dental treatment. These profit margins and patient numbers were also considered in consultation with dentists and technicians. It was confirmed that in theory, it makes sense to use these rates, but in real life, dentists or technicians stated that they would not be able to achieve the desired income with these figures. They stated that in real life if the number of teeth performed monthly is less than 200 and the price of a tooth removed by a technician is less than 2000 Turkish lira, they cannot get the desired income. For dentists, it was found that almost double the cost of labor was added to the theoretically calculated costs and that these costs should not be included in the cost calculation because they arise from other dental procedures.

Table 4.3: The Real Cost of one Tooth in Evaluated Regions.

REGION	PRICE OF DENTIST for 1 TOOTH (TRY)	PRICE FOR TECHNICIANS for 1 TOOTH (TRY)
Kadıkoy	6000	2000
Bagcilar	4500	1500
Fatih	5000	1500

4.2 RESULTS

We wanted to find out how much it costs to make dental ceramics using a methodical approach. We focused on understanding how many teeth could be prepared per month, which helped us see that there was a significant difference between the number of dentists and technicians. In fact, each technician needs to work with more than one dentist to meet the demand. This understanding shows us how collaborative this process is in the dental porcelain value chain. We also wanted to see how different rental costs in different regions would affect the final price of the tooth. That's why we chose three regions with different rental structures. Surprisingly, the theoretical price per tooth did not change much, even though rental prices were very different. This shows that our valuation method, which involves adding 50% profit to all costs during the calculation, effectively offsets the impact of rental costs on the total cost of the tooth. Since the demand process of dental porcelain ceramics starts with the dentist, we summarized the theoretical value chain in Table 4. It goes through every stage, from the dentist to the technician, to the distributor and finally to the manufacturer. This breakdown shows how much each participant contributed to the final price of the finished dental ceramics. Our in-depth analysis of the theoretical forecasting process shows that our methodology is able to maintain price consistency across regions. By incorporating a standardized profit margin, we ensured a fair distribution of value among all participants in the dental porcelain value chain. These results provide valuable information for industry professionals, policymakers, and researchers looking to improve pricing strategies and optimize the performance of the dental ceramics supply chain.

4.2.1 Analysis of the Ratio of Dentists and Technicians

One of the main objectives was to understand the dynamics of cooperation in the dental porcelain value chain. By estimating the number of teeth that can be prepared in a month, a very important discovery was made: There is a serious difference between the number of dentists and technicians. Essentially, each technician partners with multiple dentists to meet demand. This collaboration highlights the interdependence of dentists and technicians, underlining the complex network in the value chain.

The collaborative nature of the process directly affects the production capacity of dental ceramics. Our analysis has shown that the demand for dental ceramics requires close working relationships between dentists and technicians. The results highlight the importance of effective communication, coordination, and just-in-time production to meet the dynamic needs of the dental ceramics market.

4.2.2 Effect of Regional Rental Costs on Dental Costs

Three regions with different rental values were selected to evaluate the impact of rental costs on the final cost of the tooth. The aim was to evaluate how the geographic location of dental laboratories affects the overall cost of dental ceramics.

Contrary to expectations, the results showed that the theoretical price per tooth did not vary significantly, even though rental prices varied significantly between regions. This unexpected result shows that our valuation method, which includes 50% of the profit on all costs in the calculation, effectively offsets the impact of rental costs on the total cost of the tooth.

4.2.3 Dentist-Initiated Value Chain

To fully understand the value distribution in the dental porcelain ceramic value chain, we have outlined a theoretical value chain. The initiation process of dentists and the subsequent involvement of technicians, distributors, and manufacturers is systematically evaluated in Chart 4.3 and Chart 4.4.

The breakdown presented in Table 4.4 shows the specific contribution of each participant in the value chain. Dentists initiate the process, technicians bring their expertise to dental

ceramic production, distributors play a critical role in distributing products, and manufacturers provide key materials and oversee production.

Our analysis showed that distributors and manufacturers play a decisive role in determining the final price of dental ceramics. The profits allocated to these participants are critical to meeting their contributions and maintaining the economic sustainability of the entire value chain.

Table 4.4 Risk Evaluation Table.

	Maximum Theoretical price for one tooth (TL)	**Risk Evaluation**
Dentist	1.591	The price can change according to the additional employee and decrease in the number of tooth units done in one month
Technician	659	The price can change according to the additional employee and decrease in the number of tooth units done in one month
Distributor	38	This price is the invoice price for distributors, the value can be changed only according to the competitor's price change. The profit range is nearly %30 after all rent and salary expenses
Manufacturer	26	This price is the invoice price for distributors, the value can be changed only according to the competitor's price change. The profit range is nearly %30 after all rent and salary expenses

Chart 4.3: Value Chain for Dental Porcelain Ceramics.

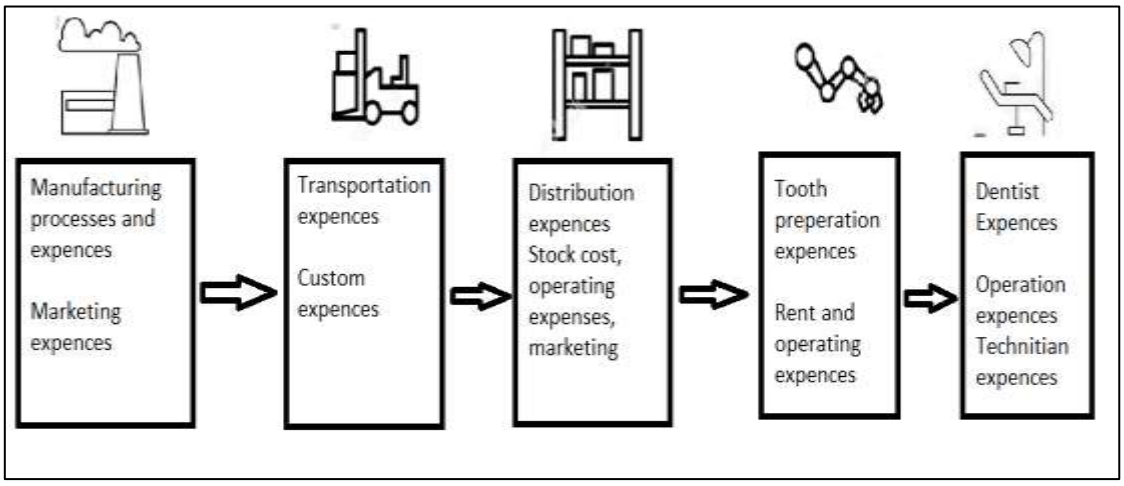
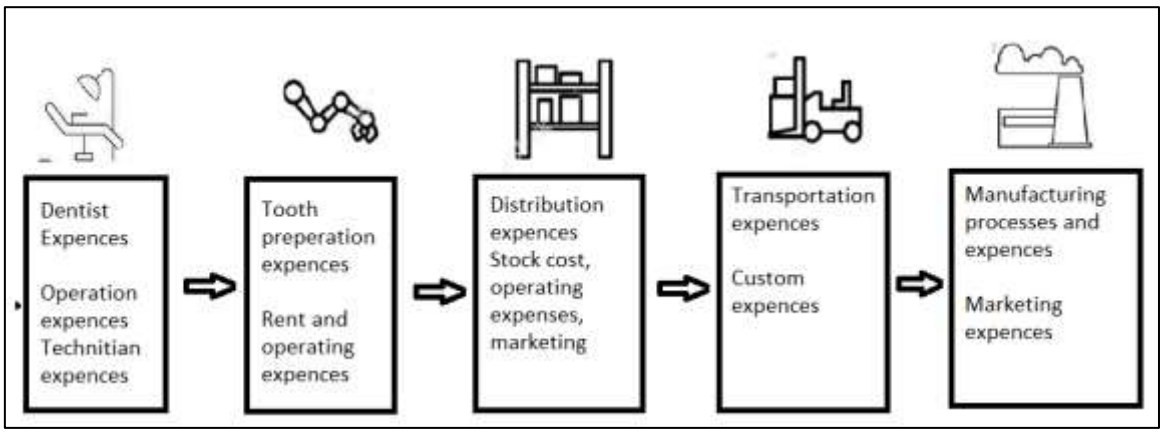


Chart 4.4: Demand Chain for Porcelain Ceramics.



5. DISCUSSION AND CONCLUSION

5.1 DISCUSSION

Our most important goal in this thesis is to learn how and what the artificial teeth that we will all encounter are made of and to understand how and why the value of the relevant product increases during this production phase. During this value chain calculation, information about theoretical calculation methods was received from several dentists and technicians. These methods were evaluated with the information on the number of patients, doctors, and technicians published by the state.

We need to discuss the theoretical calculations corresponding to actual market prices. The result of the theoretical value of one tooth shows that the price of one tooth does not change according to the rent price of the region. In each region, the price seems to be almost the same. This calculation also shows the complexity of the value chain starting from manufacturers and finishing with the dentist. Unfortunately, real price in the market for one tooth very according to the quality of the work and region. The dentist started to put a price on the tooth which does not have any calculation background. While the cost of a tooth in rich regions is 8000 TL, in crowded but low-income areas such as Bagcilar, a tooth can cost 2500 liras. When we ask dentists and technicians about the reason for this, they say the reason is the increase in the number of patients and also the increase in rental expenses. However, we have seen that rent expenses and salaries are not the reason for such a price difference. The most important criteria here actually seem to be the number of patients and the expected income. In this value chain, the only true and unchanging price is the production prices of producers and the sales price of distributors. The prices of all elements that go to the last point that can be controlled by the state do not change according to the initiative of individuals. However, since the moment the tooth-making of this product started, the prices started to vary depending on the quality of the work, time spent, and technological infrastructures, as labour was involved. According to theoretical calculations, although we see that there is no significant price change when a 50% profit is added for these, we have seen that in real life, no cost is incurred according to the calculations. In this chain, the biggest risk for manufacturers and distributors is the risk of holding stocks. It is almost impossible to know which patient will need which colour of teeth and when. Therefore, both

companies have to keep quite large stocks within their structure. These stocks are not satisfied with the variety of colours and layers. The technician must have all the products he will need. At the same time, they have to invest seriously in business development to follow the development of the world and constantly add new products to their products. Distributors have limitations in adjusting prices due to the need for different product colours and promotional efforts. Technicians, on the other hand, have more flexibility. Their ability to use dental ceramic moulds and different techniques during preparation allows them to add different levels of value depending on regional preferences. Technicians and dentists in this field have great flexibility in determining the cost of their services. This region is a small example of how economic factors influence the dental porcelain ceramics market. An important finding from our discussion is the difference in profit margins in the dental porcelain value chain.

While manufacturers and distributors calculate product expenses to differentiate stocks and products, technicians and dentists associate product profitability entirely with the workmanship and aesthetic view of the finished product. That is why Dentists invest a lot in their offices to show patients' trust in dentists and the quality of the work done.

Distribution limitations: Distributors face limitations in adjusting prices. They cannot arrange the price as they want. They need to arrange it according to the price of other well-known brands. But they have to keep in their stock a diverse range of product colours. This stock value and the promotional expenses are the biggest ones for distributors. They need to make plans to navigate the balance between maintaining profitability and responding to market demands. There is one distributor for EVOCLAR, one for GS, and SD Ceram as the manufacturer distributes its brand himself. Another limitation for distributors is new innovative products. To make the market dynamic they need to have in their stock or need to have contacts with manufacturers of technological products like 3D scanners and 3D printers. For the needs of technicians and the development of the market, distributors must follow all innovations and, if necessary, develop their supply networks to meet the needs of customers.

Technicians Flexibility: As we discussed before technicians have a higher degree of flexibility than distributors in adjusting the profit margin for one tooth. Their skills in utilizing the tooth shape by employing different techniques during preparation give the

chance to arrange the finished product price. However, the process of preparation of one tooth really needs time, the competition between technicians is not related to the regions but related to the quality of the tooth they prepared and the time. Some technicians use digital systems like 3D printers, 3D scanners, Lithium disilicate, and other techniques to prepare many more teeth in one day. The region can play a role in adjusting the price for technicians only in one way. If their work is of the highest quality they work with dentists who work in areas where the population has higher incomes compared to other regions.

Local Economic Factors and Pricing Flexibility;

As a case study for discussion, we can take the region Kadikoy in Istanbul. The difference in local economic factors like higher expenses and high-income levels can be evidence for discussion. In this area, technicians and dentists exhibit high flexibility in setting values for their services. Another factor may also be because the population rate is high in this region. Almost all companies that have services have their location in Kadikoy. That is why the income is also very different between the population in Kadikoy. We only can see very clearly that the price variation is not related to the rent and other expenses in the region itself. The economic factors affect the price fluctuation of the value chain of dental ceramics. Technicians and dentists who work in different regions with different economic profiles are free to determine their service values to the local demands of these regions.

The main discussion should be related to how the value chain of the dental market can be standard and fair. From this discussion, we can see the main roles and the impact of these roles on the value chain of dental ceramics. All units in the value chain have a very important role and have high effort. By understanding the dynamic nature of profit margins and the challenges faced by manufacturers and distributors, we can see that the price for a finished product can be almost the same in all regions if the profit margin can be stabilized. If the government ensures that the service fee for the work performed by dentists and technicians is set at a certain rate, it is expected that the theoretical price and the real price range will not be this high. Apart from that, the inspections and price registration processes regarding dental ceramic materials and other materials followed by the Ministry of Health play an important role in the application of dentists and technicians.

5.2 CONCLUSION

In this study, the importance of the dental ceramics market and the value chain of dental ceramics are evaluated. Along with the increase in value, the technological evolution has also increased in the dental market. These evolutions become an important issue because the market demand for dental ceramics has increased. This demand increase started because people's understanding of dental health has changed seriously. Dentists, technicians, and manufacturers had to constantly improve themselves as they were faced with innovative products almost every year. In today's world, the dental market shows serious income. But to gain a share of this dental market, manufacturers, technicians, and dentists have to improve themselves in these advanced technologies.

In conclusion, our discussion of the dental porcelain ceramic value chain shows that there is a significant difference between theoretical calculations and the actual market price. The difference between actual market prices and the theoretically calculated value is not related to the calculation method. It is entirely because dentists and technicians can determine their fees for the service. The results of interviews with dentists and technicians provide a comprehensive understanding of the complexities of determining the value of the finished product.

When we consider the roles of manufacturers, distributors, technicians, and dentists in the value chain among themselves, we see that each of them individually has very high effort. While manufacturers strive to create new innovative products to keep up with global trends, distributors face restrictions on product range and promotions, technicians use their skills in preparation of the tooth which deserves to be almost the same as natural ones, and dentists improve themselves to meet patient’s needs. All of these add unique value to their business.

Dentists, as an important part of this value chain. The success of the treatment used by dentists in a patient's mouth is as important as the structure and appearance of the tooth used. People only know dentists. Since the public does not know the other important players in the value chain that we have mentioned in the dissertation, dentists have no choice but to adhere to the set prices. That is why the demand for this chain starts from dentists. They have the responsibility to provide the color and the shape of the tooth that the patient needs. Technicians use this information to decide which color or material they need to prepare the

request. Distributors make analysis related to the demand request and organize stock in their warehouse. Manufacturers also plan their stock related to the demand from distributors from all over the world.

This thesis contributes to our understanding of the dental porcelain ceramics industry by combining theoretical frameworks and real-world market dynamics. It highlights the need for the dental industry to optimize production, distribution, and pricing strategies. Our research on the dental porcelain ceramics industry value chain creates a comprehensive understanding from the combination of theoretical frameworks, real market dynamics, and the opinions of experts in this market.

Insights from Industry Experts: The validation process went through numerical comparisons and evaluated qualitative information from industry experts. Interviews with dentists, technicians, and distributors provided a qualitative contribution to our understanding by providing a multifaceted perspective on the dental ceramics industry. Basing the theoretical knowledge used on the practical complexities of the market has enriched our academic research and created the opportunity for us to work on a subject that has never been evaluated until now.

Examining profit margin differences between dentists, distributors, and technicians reveals the different roles of each player in the value chain. Distributors operate in a framework that requires balancing profitability by facing the risk of maintaining the stock with different product assortment and promotional efforts. This shows the challenge distributors and manufacturers face in adapting and proposing the ever-changing dynamics of the dental ceramic market.

On the other hand, technicians display masterpieces. Their ability to create artificial teeth from powders by using a variety of techniques gives them flexibility in price evaluation.

Shaping Pricing Strategies: While investigating specific regional considerations provides a view of how local economic factors shape pricing strategies. High expenses and income levels in Kadikoy give technicians and dentists more flexibility in determining value for their efforts. This case study reinforces the idea that local economic factors significantly impact the dental porcelain ceramic market, highlighting the need for adaptable strategies across the value chain.

Results from regional assessments go beyond descriptive observations and carry practical insight for professionals. Understanding the interplay between local economic factors and pricing flexibility allows stakeholders to develop strategies related to the specific needs and dynamics of different regions. This adaptability emerges as an important determinant in optimizing production, distribution, and pricing strategies in the dental ceramic industry.

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