INNOVATION IN ESTAŞ

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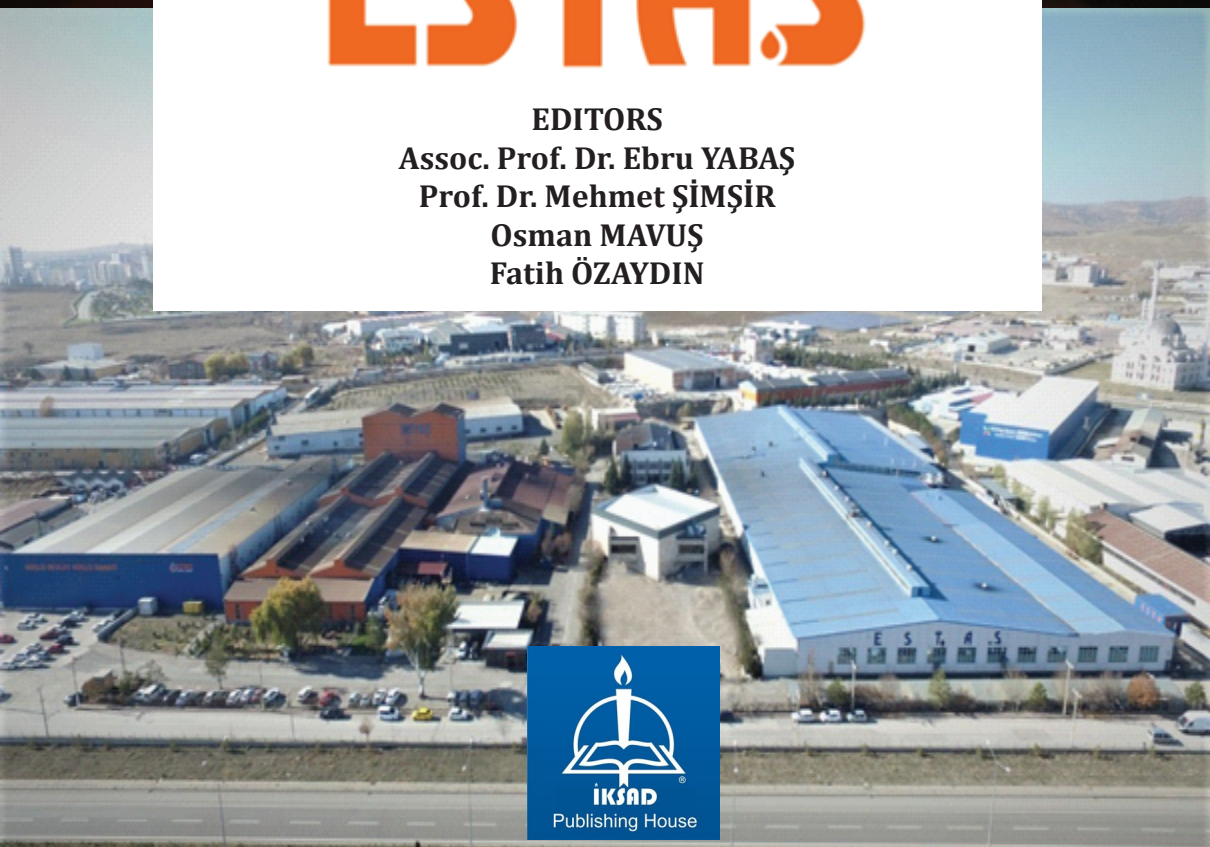

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This book is dedicated to the 50th anniversary of ESTAŞ and the 50th anniversary of Sivas Cumhuriyet University.

CONTENTS

PREFACE

ESTAŞ has managed to provide solutions for the needs of industrial sectors as a manufacturer known for its safety, efficiency and quality over the years. Its expertise from medicine to the production of advanced technological materials has become a symbol of safety and performance worldwide. ESTAŞ aims to be a source that will inspire all stakeholders in the sector by displaying its unique experiences and continuous development efforts in production technologies. The studies carried out in a wide range from a wide range of products to the development of new methods based on technology are an indication of the importance ESTAŞ gives to innovation. This book is an important study reflecting ESTAŞ's valuable contributions and achievements in the field of industrial production. This book mainly aims to examine in depth ESTAŞ's different production processes, R&D activities and innovative products it has brought to the sector. We also believe that this study will create a deeper understanding of all kinds of innovations, achievements and developments made by ESTAŞ from its history to the present. The studies described in the book will also be a starting point for new research in the field of occupational safety and production technologies. On the other hand, ESTAŞ cooperates with universities within the scope of university-industry cooperation and carries out cooperation in developing innovative technologies, product design and improvements. This cooperation creates many opportunities for both parties and provides contributions especially in areas such as R&D, innovation and regional development. In the writing of this book, ESTAŞ received support from the academic staff of Sivas Cumhuriyet University, from whom it received academic consultancy.

While preparing this book, we congratulate ESTAŞ's success and importance in the sector and thank everyone who contributed and contributed.

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CHAPTER 1

THE ROLE OF STRATEGIC LEADERSHIP IN FOSTERING INNOVATION AND INTRAPRENEURSHIP AT ESTAŞ

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INTRODUCTION

Founded in 1977, ESTAŞ is Turkey's first and largest camshaft manufacturing facility. Initially focused on producing spare parts, the company expanded its operations in 1979 to produce camshafts for Original Equipment Manufacturers (OEMs). Today, ESTAŞ supplies camshafts to 16 automotive manufacturers globally, and exports its products to 46 countries, serving both the OEM and aftermarket segments. With over 2,500 different camshaft models and 1,100 employees, the company generates an annual revenue of $40 million. ESTAŞ operates from a facility spread across 182,000 square meters, with a commitment to innovation and sustainability. In 2023, ESTAŞ's export distribution by continent is as follows: Europe accounts for 54.14% of total exports, America for 39.72%, Asia for 3.35%, Austria for 2.13%, Eurasia for 0.61%, and Africa for 0.04%.

Strategic Leadership and Innovation at ESTAŞ

The **TÜBİTAK 2244 Industry PhD Program** supports **ESTAŞ's external growth strategies and global restructuring processes** aimed at establishing a stronger global identity. This project, in collaboration with academic experts, focuses on enhancing ESTAŞ's competitiveness in international markets by developing strategies **for market expansion, innovative product development**, and operational **optimization**. One important project is related with Strategical Leadership.

Strategic leadership is a critical concept that ensures an organization can align its long-term goals with a rapidly changing external environment. Pisapia (2006) defines strategic leadership as the capacity to proactively navigate through uncertainties and challenges, aligning organizational goals with the dynamic market. At ESTAŞ, strategic leadership goes beyond top management, reaching all levels of the organization. This decentralized approach allows for a culture of innovation and intrapreneurship, enabling employees at every level to contribute to the company's innovation-driven growth.

- ESTAŞ's approach to leadership is central to its success, emphasizing the importance of innovation and intrapreneurship (internal entrepreneurship). By encouraging leadership at all levels and fostering an organizational culture that supports innovation, ESTAŞ has maintained its competitive edge in the global market. This paper explores how strategic leadership at ESTAŞ drives innovation and intrapreneurship, with a focus on

how workplace well-being, autonomy, and organizational climate contribute to this relationship.

- By encouraging a culture of innovation, ESTAŞ has not only improved its production efficiency but also enhanced its ability to meet the ever-evolving demands of the global automotive industry. The strategic leadership approach at ESTAŞ ensures that innovation is embedded in the company's DNA, driving long-term success and sustainability.

The transformation in ESTAŞ's leadership strategy, particularly around **2013**, can be directly linked to the principles of **transformational leadership**, a leadership style that encourages change, innovation, and continuous growth by inspiring and motivating employees at all levels.

In **2006**, the decision to part ways with the marketing team indicated a shift in the company's approach to its operations. This period represented a challenging phase, but it also laid the foundation for a more strategic and dynamic leadership style. By **2013**, ESTAŞ embraced transformational leadership as its primary model, focusing on fostering innovation, employee engagement, and organizational change.

This shift in leadership philosophy manifested in the significant jump in camshaft sales, from 324,098 units in 2007 to 413,749 units in 2013. The new leadership mindset encouraged a culture of **intrapreneurship**, where employees were empowered to take initiative, propose new ideas, and drive the company's growth. Transformational leaders at ESTAŞ motivated their teams to align with the company's evolving goals, resulting in increased efficiency and innovation.

Key aspects of transformational leadership visible in ESTAŞ's growth during this time include:

- **Inspirational Motivation**: Leaders communicated a compelling vision of the future, instilling a sense of purpose and direction among employees.

- **Intellectual Stimulation**: Employees were encouraged to challenge the status quo and think creatively, contributing to innovative product development, including new lines in medical devices, hydraulic components, and gears.

- **Individual Consideration**: Leaders focused on employee development, investing in their skills and ensuring personal growth aligned with the company's long-term objectives.

The results of this leadership transformation were evident in the subsequent years. By **2023**, camshaft sales had skyrocketed to **1,354,952 units**, a clear reflection of how transformational leadership fostered a culture of innovation and empowered employees to contribute to the company's growth.

Looking ahead, the strategic goals set for **2033**, which aim for even stronger sales growth, further emphasize the ongoing influence of transformational leadership at ESTAŞ. The company's leadership continues to prioritize adaptability, continuous improvement, and a commitment to innovation, ensuring long-term sustainability and success in a competitive global market.

In conclusion, the leadership shift in **2013** aligned perfectly with the principles of transformational leadership, helping ESTAŞ navigate challenges, inspire innovation, and achieve remarkable growth. This leadership style continues to shape the company's strategic vision and will be critical to meeting its ambitious future goals.

Timeline of Strategic Milestones at ESTAŞ

Over the years, the company has expanded its operations and diversified into various sectors, including manufacturing, medical technology, education, and renewable energy. Below is a timeline that highlights the key strategic milestones in ESTAŞ's development:

- **1977**: Establishment of ESTAŞ as a camshaft manufacturing company.
- **1991**: Opening of the casting factory to further strengthen its manufacturing capacity.
- **2000**: Launch of the ES-1 machining factory to expand production capabilities.
- **2003**: Opening of a new, state-of-the-art casting factory.
- **2006**: ESTAŞ began producing fuel pump shafts for Original Equipment Manufacturers (OEMs), marking its entry into a specialized automotive components sector.

- **2011**: The company received R&D center certification, formalizing its commitment to research and innovation.
- **2014**: Establishment of ESTAŞ Medical, demonstrating the company's diversification into the medical technology sector.
- **2018**: Opening of the ES-2 camshaft manufacturing factory and the ES-3 gear and powder metallurgy production lines, further expanding its production capabilities.
- **2019**: Inauguration of a new production line for heavy vehicle camshafts, catering to a broader market segment.
- **2020**: Opening of a new heat treatment facility and the establishment of a dedicated fuel pump production area. Additionally, ESTAŞ launched a motor block production line and received AS9100 certification, indicating its compliance with aerospace industry standards.
- **2021**: Establishment of the ESTAŞ Education Center and the Digital Design and Application Center (Digident), emphasizing the company's focus on employee development and innovation.
- **2022**: Opening of the ESTAŞ Glove Factory and the establishment of ESTAŞ Tava, a division dedicated to producing cast iron cookware, marking another step in its diversification strategy.
- **2023**: Launch of production lines for housing/cover/control blocks, as well as new lines for aviation and orthopedic prosthetics, positioning ESTAŞ as a key player in specialized high-tech manufacturing sectors.
- **2024**: ESTAŞ continues to expand into renewable energy with the commissioning of RES (Renewable Energy Systems) investments

Supporting Employee Intrapreneurship

Intrapreneurship refers to entrepreneurial behaviours within an organization, where employees are empowered to act like entrepreneurs by generating new ideas, taking risks, and implementing innovative projects that contribute to the organization's growth (Gawke et al., 2018). ESTAŞ places significant emphasis on intrapreneurship, encouraging employees to take ownership of their work and pursue initiatives that align with the company's strategic goals.

The company supports intrapreneurship by providing employees with the autonomy and resources needed to develop and implement innovative ideas. ESTAŞ's leadership understands that intrapreneurship is key to staying competitive, particularly in an industry as dynamic as automotive manufacturing. Employees are encouraged to experiment with new processes, improve existing production techniques, and even explore new product lines. For example, ESTAŞ has developed specialized camshafts for a wide range of engines, enabling the company to expand its product portfolio and increase its market share. Employee intrapreneurship is a vital process that helps organizations acquire new skills, improve performance, escape stagnation, and capture dynamism, all while expanding into external markets and enhancing performance. In today's rapidly evolving business world, where the boundaries of traditional industries are being redefined at an unprecedented pace, both leaders and employees must rethink their approaches for success. The complexity of the modern business environment and the intensity of competition push organizations to be more flexible, innovative, and open to change. In this context, intrapreneurship plays a critical role.

Intrapreneurship at ESTAŞ means employees act with an entrepreneurial spirit within the organization, developing new projects and bringing them to life to create value for the company. This practice enhances the innovative potential of the organization. At ESTAŞ, employees continually come up with new ideas, contributing to the company's competitive edge in the global automotive industry. For example, the establishment of **ESTAŞ Medikal** in 2014, a subsidiary focused on healthcare technologies, was a direct result of internal innovation efforts. Similarly, the **2018 launch of the ES-2 and ES-3 gear and powder metallurgy production lines** emerged from internal initiatives aimed at expanding product offerings in response to market demands.

In today's changing work environment, innovation is the key to sustainable competitive advantage. Intrapreneurs at ESTAŞ continuously prepare the company for these changes by bringing forward new ideas that contribute to the development of new product lines, such as **medical devices, inhalation conteiner and hydraulic systems**. These internal projects ensure that the company remains adaptable to industry shifts, thereby extending its longevity and market relevance.

One of the benefits of intrapreneurship is the opportunity it provides for employees to refine existing work processes or integrate new technologies

into the organization. At ESTAŞ, intrapreneurs have been instrumental in improving operational efficiencies through **CNC grinding technology** in camshaft production. This integration has significantly boosted production accuracy and efficiency, setting the company apart in a highly competitive industry.

Intrapreneurship also aids in the development of leadership skills within the organization. Employees who lead internal projects at ESTAŞ gain valuable experience in managing projects, assessing risks, and leading teams. This aligns with the **transformational leadership** model that ESTAŞ adopted in **2013**, where leadership was decentralized, empowering employees at every level to take initiative and lead innovation efforts.

Intrapreneurship fosters a culture of innovation within the organization. ESTAŞ's **Digital Design and Application Center (Digident)**, established in **2021**, is an example of how the company has institutionalized this culture. The center encourages employees to freely share their ideas, leading to continuous improvements in product design and process efficiency. This innovative environment is further strengthened by the company's **R&D center**, which has been operational since **2011**.

At ESTAŞ, intrapreneurs have the opportunity to collaborate with employees from different departments and disciplines. This cross-functional collaboration promotes a more effective teamwork environment. For example, the development of **ESTAŞ Glove**, launched in **2022**, required the integration of expertise from the medical, engineering, and manufacturing teams, showcasing the power of cross-departmental collaboration in driving innovation.

Intrapreneurship also helps organizations improve their risk management capabilities. The experiences gained from managing risks and uncertainties in new projects contribute to increasing ESTAŞ's overall risk management capacity. With the **launch of the new heavy vehicle camshaft production line in 2019,** the company demonstrated its ability to navigate the risks associated with entering new markets and scaling production capabilities.

Exploring New Market Opportunities: Intrapreneurs are often instrumental in helping organizations explore new market opportunities. At ESTAŞ, intrapreneurs have been key in identifying new segments beyond traditional automotive parts, such as **orthopedic prosthetics, aviation**

components, and renewable energy systems introduced between **2020 and 2023**. These new ventures have opened additional revenue streams and solidified ESTAŞ's position as an innovative leader in multiple industries.

Furthermore, ESTAŞ's approach to intrapreneurship is supported by a collaborative environment, where teams across departments work together to solve problems and capitalize on new opportunities. This collaborative approach ensures that innovation is not limited to a single department but is a company-wide effort that involves every employee.

ESTAŞ has demonstrated remarkable success in research, development, and innovation across various fields, as evidenced by the following accomplishments:

- 686 R&D Center Projects: A testament to ESTAŞ's commitment to research and innovation, contributing to industry advancements.
- 59 TEYDEB Projects: These include 24 TEYDEB 1501, 1 TEYDEB 1511, 32 TEYDEB 2241, 1 TEYDEB 2242, and 1 TEYDEB 2209, showcasing a strong focus on competitive technological development.
- 4 San-Tez Projects: Collaborative projects integrating university research with industry needs.
- 1 European Union Project: Participation in international research initiatives.
- 1 Ministry of Trade KTZ Project: A significant national project, supporting trade and economic growth.
- 42 Student Project Groups: Engaging and nurturing young talent through practical, hands-on projects.
- 53 Intern Engineers: Providing future engineers with valuable industry experience.
- 29 Patents: Highlighting ESTAŞ's capacity for innovation and intellectual property development.
- 14 Utility Models: Practical innovations that offer improvements to existing technologies.
- 3 Industrial Designs: Contributions to industrial design, reflecting creativity and functional innovation.

- 73 Special Machinery Designs and Production: Custom machine design and production for specific industrial needs.
- 96 National and International Publications: Sharing research and findings with the global academic and professional communities.
- 823 Participation in Fairs, Symposia, and Seminars: Engaging with the broader industry and academic networks through active participation in professional events.
- 638 Training Participation: Commitment to continuous learning and skill development within the workforce.
- InovaLIG Awards for 2018 and 2019: First Place National recognition for excellence in innovation leadership.

These accomplishments highlight ESTAŞ's strategic emphasis on R&D, innovation, and active participation in national and international collaborations, driving progress across multiple industries.

Innovation through Collaboration and R&D

Research and development (R&D) is a cornerstone of innovation at ESTAŞ. The company has established a robust R&D department that works closely with universities and research institutions to drive technological advancements. For example, the SANTEZ project, conducted in collaboration with Sivas Cumhuriyet University, has led to significant innovations in the design and production of camshafts. This project involved the development of CNC grinding machines and mathematical modelling to optimize production processes (Közkurt, 2017).

ESTAŞ has embraced this leadership philosophy by establishing systems and structures that allow employees to take initiative and contribute to the company’s innovative processes. Leaders at ESTAŞ encourage employees

to challenge the status quo, explore new ideas, and develop innovative products and processes. One key example is the company’s collaboration with academic institutions, such as Sivas Cumhuriyet University, which has led to technological advancements in camshaft production through the use of CNC grinding technology (Ertaş, 2016).

A key example of ESTAŞ’s strategic leadership in action is its collaboration with academic institutions such as Sivas Cumhuriyet University.

This partnership has led to significant advancements in camshaft production. ESTAŞ's R&D unit, in cooperation with the university's Mechanical Engineering Department, has developed cutting-edge CNC grinding technology for high-speed production of camshafts. This collaboration reflects the strategic leadership model that embraces external knowledge and resources to push the boundaries of innovation (Bagirov & Ertaş, 2009).

In addition to advancing its core business in camshaft manufacturing, ESTAŞ has expanded into other sectors, including medical technology. The company has developed medical devices such as aspiration catheters and Y-connector systems for surgical procedures (ESTAŞ Medikal, 2024). These innovations demonstrate how ESTAŞ leverages its R&D capabilities to diversify its product offerings and explore new market opportunities.

The collaborative approach to R&D at ESTAŞ not only fosters innovation but also ensures that the company remains at the forefront of technological advancements in the manufacturing sector. By working closely with academic experts and investing in cutting-edge technologies, ESTAŞ continues to push the boundaries of what is possible in camshaft production and beyond. The projects include the design and production of an aspiration catheter for the aspiration of bodily secretions, the design and production of a drip control set for the regulated administration of IV fluids in intensive care units, the design and production of a Y-connector system for different fluid applications through a single vascular access in cardiovascular and thoracic surgery procedures, and the design and production of a manifold set used in angiography and PTCA (percutaneous**.** transluminal coronary angioplasty) procedures. (Ada, F. in process 2024).

1. Camshaft Produ

- ESTAŞ is widely recognized for its high-quality camshaft and pump shaft production, serving both automotive and heavy-duty machinery industries.
- It also produces rotor shafts and thru-drive shafts.
- The company applies advanced production technologies such as CNC grinding, ensuring the highest precision in its products.

2. Medical Solutions

- ESTAŞ Medikal focuses on producing cutting-edge solutions such as dental prostheses, implants, orthopedic devices, and tumor and trauma prostheses.
- The company also specializes in producing custom-made medical devices, leveraging digital technologies for better patient outcomes.

3. Automotive and Aerospace

- For the aerospace industry, ESTAŞ manufactures, sockets, and other specialized parts using high-precision manufacturing processes.
- ESTAŞ is also involved in advanced robotic activities and optical inspection systems, further integrating cutting-edge technology into its automotive and aerospace production lines.

4. Educational and Development Initiatives

- Through ESTAŞ Akademi, the company offers technical training, personal development programs, and conferences, aimed at enhancing employee skills and fostering a culture of continuous learning and development.
- These efforts ensure that employees remain at the forefront of innovation, equipped with the necessary skills to drive further growth within the organization.

5. Environmental and Energy Solutions

- ESTAŞ Energy Systems focuses on renewable energy investments, particularly in wind energy through RES investments.
- The company also conducts energy analysis and optimization, demonstrating its commitment to sustainability and environmental responsibility.

6. Production Technology and Research and Development

- ESTAŞ is deeply committed to research and development (R&D) efforts, which are highlighted by its Digital Design and Application Center (DTUM).

- The company engages in a variety of manufacturing processes such as forging, casting, and surface treatment.

- It applies additive manufacturing techniques and employs modern 3D printing technologies for rapid prototyping and the production of complex components.

7. Protective Equipment

- Under the ESTAŞ Eldiven brand, the company produces surgical gloves, sterile gloves, and protective gear for medical and industrial applications.

- These products meet international standards for quality and safety, including certifications from PPE, CE, FDA, and TSE.

ESTAŞ R&D Center Performance Rankings (2018-2023)

ESTAŞ has consistently performed well in key R&D metrics over the years. Below is a summary of its rankings across different categories from 2018 to 2023:

- **R&D Spending (Top 250 Companies)**: ESTAŞ has maintained a solid presence among the top 250 companies based on R&D expenditures. The company ranked 92nd in 2018, peaking at 158th in 2023, showing its sustained commitment to R&D investment.

- **Number of Projects Conducted at the R&D Center (Top 100)**: ESTAŞ's project count has varied, with notable rankings such as 63rd in 2018, 89th in 2022, and 76th in 2023. This demonstrates the company's active involvement in innovative project development.

- **Total Number of Employees at the R&D Center (Top 100)**: The company consistently ranked in the top 100, with employee counts peaking at 98th in 2021 and maintaining a steady position in the 90s range in subsequent years.

- **Number of National Patents Obtained (Top 50)**: ESTAŞ achieved significant success in securing patents, with a ranking of 11th in 2020 and maintaining a strong performance in 2021 (42nd) and 2022 (29th).

- **Number of Utility Models Obtained (Top 50)**: In terms of utility models, the company was ranked 2nd in 2019 and 26th in 2022, showing its ability to produce practical innovations that improve existing technologies.

ESTAŞ collaborates with a wide range of institutions across various sectors, including R&D centers, universities, and member organizations. These partnerships play a crucial role in driving innovation, research, and development within the company. The collaboration network includes the following entities:

R&D Centers and Companies:

- Anova
- BİAS Engineering
- Figes Engineering
- InfoTRON
- Renault
- Ford
- Türk Traktör
- Cadem

Universities:

- İstanbul Technical University (İTÜ)
- Atılım University
- Kocaeli University
- Karadeniz Technical University
- Erciyes University
- Erzurum Technical University
- Cumhuriyet University
- Tokat Gaziosmanpaşa University

Member Institutions:

- The Scientific and Technological Research Council of Turkey (TÜBİTAK)
- Ministry of Science, Industry, and Technology of Turkey
- Sivas Chamber of Commerce and Industry

- Chamber of Metallurgical Engineers (TMMOB)

These collaborations support ESTAŞ in achieving its innovation goals, enhancing its research capabilities, and maintaining its leadership in technology and product development across industries.

Encouraging a Culture of Innovation and Autonomy

Intrapreneurship thrives in environments that offer autonomy, a factor closely tied to workplace well-being and organizational climate (Gawke et al., 2018). ESTAŞ fosters this environment by empowering employees at all levels to take ownership of their projects and ideas. The strategic leadership at ESTAŞ is committed to creating an organizational climate that supports creativity, risk-taking, and innovation, aligning with the broader concept of transformational leadership, which Bass and Avolio (1990) highlight as critical for encouraging innovation and individual empowerment.

Research has shown that autonomy, coupled with a supportive organizational climate, enhances employee innovation and intrapreneurial activities (Carmeli, 2007). ESTAŞ has implemented leadership practices that ensure employees have the freedom to innovate while being supported by a strong leadership framework. This approach has proven effective in improving both employee well-being and the company's overall performance.

The Impact of Leadership on Organizational Climate

Strategic leadership at ESTAŞ has created an organizational climate that supports both innovation and intrapreneurship. Organizational climate refers to the shared perceptions of the work environment, which can significantly impact employee motivation, creativity, and performance (Naktiyok, 2024). At ESTAŞ, leadership behaviors such as open communication, trust, and support for employee initiatives have fostered a positive climate where innovation can flourish.

The company’s leadership encourages a culture of risk-taking, where employees are not afraid to experiment with new ideas. This psychological safety is critical for fostering intrapreneurship, as employees are more likely to engage in entrepreneurial behaviors when they feel supported by their leaders (Zhong & Bartol, 2010). In addition, the company’s focus on workplace well-being ensures that employees are motivated and engaged, further enhancing their ability to contribute to innovative projects.

ESTAŞ's leadership also recognizes the importance of autonomy in fostering innovation. By giving employees, the freedom to make decisions and pursue new ideas, ESTAŞ empowers its workforce to take ownership of their work and drive the company's innovation agenda. This autonomy, combined with a supportive organizational climate, creates a fertile ground for intrapreneurship to thrive.

Conclusion: Strategic Leadership as a Catalyst for Growth

Strategic leadership at ESTAŞ extends far beyond traditional management practices. By promoting a culture of innovation, decentralizing leadership responsibilities, and empowering employees to take an active role in the company's growth, ESTAŞ has positioned itself as a leader in the global camshaft manufacturing industry. The company's strategic partnerships with academic institutions and its commitment to fostering intrapreneurship have enabled it to remain at the forefront of technological advancements, driving both efficiency and innovation.

As the global market continues to evolve, ESTAŞ's strategic leadership approach will undoubtedly serve as a model for other organizations looking to balance innovation with operational excellence. By placing leadership and innovation at the heart of its business strategy, ESTAŞ is well-equipped to navigate the challenges and opportunities of the future.

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CHAPTER 2

CAMSHAFT DESIGN AND ESTAŞ A.Ş

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INTRODUCTION

Camshafts consist of an off-axis cam connected to a shaft with a circular motion and a follower with an intermittent linear motion or a limited angular motion that follows the profile surface of this cam (Közkurt,2017).

Camshafts used in internal combustion engines convert the circular motion they receive from the crankshaft, which is the main shaft of the engine, into linear motion with the follower mechanism, thus providing the opening and closing of the intake and exhaust valves in the cylinder heads, in other words, the gas exchange in the engine cycle (Bagirov, Ertas, 2009). Depending on the profile geometry of the camshafts, the change in the kinematic values of position (S), speed (v), acceleration (a) and jerk (j) affects the efficiency of the engine.

In order for cam followers to provide the desired kinematic values, a sensitive cam profile determination is required. For this purpose, ESTAŞ AR-GE unit carries out the optimum cam curve design with reverse engineering service in accordance with the demands from the customer. For this purpose, together with AR-GE engineers, within the scope of University-Industry cooperation, SCU. Engineering Faculty Mechanical Engineering Department Graduate Programs have strengthened the AR-GE unit with SANTEZ-projects carried out.

1. CAMSHAFT PRODUCTION

In periodic camshafts, cam geometries are designed with curves drawn eccentrically from the basic circle axis to obtain the desired rise-fall values in a period. In multi-cylinder engines, all valves proportional to the number of cylinders are controlled by cams placed on a single shaft or two simultaneously working shafts. For this purpose, the designed cam elements are positioned at different angles on the shaft or shafts to create a camshaft unique to each engine. Thus, camshafts support the continuity of the engine cycle by sending the air-fuel mixture to each cylinder at different times and removing the waste gases after combustion/explosion from the cylinder.

The cam profile is designed by utilizing approaches such as mechanism technique, machine dynamics, internal combustion engine theory, thermodynamics, mechanical vibrations and design geometry (Közkurt,2017).

Camshafts designed at ESTAŞ AR-GE have production methods such as reducing steel of certain diameters or forged steel or cast steel with a rough

shaft shape to a precise profile through machining, or by machining each cam separately and assembling it in a plug-in manner on a shaft.

After machining, ESTAŞ manufactures camshafts, which are cemented in its Heat Treatment unit, to provide protection against oxidation and increase surface strength. Camshaft production in our country is carried out by a small number of corporate companies (Ertaş, 2016). ESTAŞ A.Ş., established in 1977, is the first and largest camshaft production facility in Turkey that manufactures camshafts in our country. ESTAŞ, which manufactured for the spare parts market in the early years, began to manufacture camshafts for key industry companies (OEM) in 1979.

The development of production technologies in the machinery industry has allowed much more precise and faster production of camshafts. In the past, camshafts were produced with milling machines, but now they are mostly produced with cylindrical grinding. The advantages of high speed in cylindrical grinding and high peripheral speed obtained on the large diameter of the cylindrical wheel provide low surface roughness in production (Közkurt,2017). The creation of the cam profile on the production bench was first done by copying, then with Numerical Control (NC) machines and finally with Computer Aided NC (CNC) machines (Közkurt,2017).

2. DESIGN OF CAM PROFILE

Since the main goal in a cam mechanism is to control the movement of the follower, the follower motion curve is designed before the cam profile design. Various curve function approaches are used in the design of the follower motion curve. These can be listed as simple harmonic, parabolic, cycloid, trapezoidal acceleration, third degree, double harmonic and polynomial motion curve functions (Söylemez, 2008). All or parts of these curves primarily form the position, or S graph, of a follower, and the derivatives of S form the velocity, acceleration and jerk graphs. Since the S curve, called the motion curve, is obtained from the continuous functions mentioned above, it needs to be discretized. Discretization is obtained by giving the angle values one by one to the angle parameter of the continuous function at the resolution required for production, or by writing the function in a software such as MATLAB®, Mathcad, Excel and using the data set of the desired resolution belonging to the angle as input. The data of S, whose function is selected and discretized, is used to obtain the cam profile. There are two different methods used to obtain the cam profile. The most well-

known and widely used of these is the analytical approach, while the less well-known and rarely used is the graphical approach, in other words the geometric approach.

2.1 Graphical Approach

The graphical approach is more cumbersome as it is performed by finding the contact points of the cam profile of the tracker at each sampling angle progressively through the tracker motion graph. However, it is an easier method to understand than the analytical approach since it explains the visual stages. In the analytical approach, a model is obtained using variables such as the follower position, contact angle, and the Cartesian or polar coordinates of the cam profile are obtained from this single model. The pressure angle used in the analytical approach is a function depending on the derivative of the follower position, that is, its speed. In cases where the motion function of the follower is unknown and instead a data set is available, the profile calculation can be made by estimating the speed with numerical derivative approaches. Another reason why the graphical approach does not include derivative variables is advantageous over the analytical approach. In this section, the analytical and graphical approaches are explained by giving their equations and drawing stages. The camshafts produced in CNC grinding are generally high-speed radial camshafts, and these camshafts mostly have flat and round followers.

2.2 Analytical Approach

In the analytical approach generally used to obtain the polar or Cartesian coordinates of the cam profile, inverse kinematics is applied. In inverse kinematics, the cam profile is assumed to be fixed and the follower is assumed to perform both rotational and translational motions. The direction of rotation of the follower is taken opposite to the direction of rotation of the cam. With this assumption, the formation of the profile envelope can be easily understood when the process is considered visually. In fact, since there is no profile at first, the rotation of the profile is out of the question. In other words, the inversion approach is also explained as a method of creating an envelope by only performing the follower movement. In the flat follower, the coordinates of the contact points of the cam profile and the follower are obtained, while in the round follower, the field curve consisting of both the contact points and the center points of the follower (pitch curve) coordinates are obtained. Especially in round follower cams, the pressure angle, which is a

function of the velocity that is the derivative of the position, also changes. This is one of the most basic and important cam profile calculation concepts. In addition, the fact that flat follower cams are produced on CNC grinding machines using circular cutters plays an important role in understanding the analytics of the round follower cam mechanism. At ESTAŞ A.Ş, cam profile design is production-oriented. Therefore, since a centric follower mechanism approach is applied in CNC grinding, cases where the translation axis of the follower does not pass through the rotation axis of the cam are not considered.

The round follower translation type, which is considered as a type of cam mechanism, also forms the basis of orbit determination in camshafts produced with CNC grinding or CNC milling. Because the cutters used in grinding and milling have round profiles. If the diameters of the cutter and the follower are the same, the profile can be obtained by assigning the follower orbit, that is, the field curve, to the cutter without the need for a new orbit design. However, the cutter diameter being the same as the follower cannot always be achieved in production. The cutting wheel diameters are selected large for faster chip removal, and the diameters of the milling cutters are not very variable and are selected as small diameter drill bits. In this case, a different orbit is formed from the orbit of the follower, provided that it is perpendicular to the pressure tangency of the follower to the cam surface. The cutter or cutting wheel following the new orbit has a variable follower eccentricity. This situation requires the cutter or cutting wheel to be controlled in two axes. Otherwise, in the case where there is no eccentricity, the correct profile cannot be obtained since the contact angle of the cutter or cutting wheel will also change. In such a case, production can only be carried out by finding the angles at which the cutter or the stone presses on the same contact points as the viewer and creating a new angle-position sign (Közkurt,2017).

The analytical approach used in the literature to obtain the cam profile is explained and discussed through Figure 2.1. In Figure 2.1, the base circle of the cam profile, the base circle of the follower orbit, the cam profile and follower orbit geometries; follower position, pressure angle, cam angle and orbit radius variables and follower radius and base circle radius constants can be seen. In order to obtain the cam profile geometry in the form of coordinates, the S curve containing the position information of the follower should be used. However, the data set belonging to the S curve is not sufficient on its own. In the analytical approach, the velocity, namely the v curve, which is the derivative of S, is also used in the calculations.

Interestingly, v is numerically equal to the length of |FO| seen in Figure 2.1 (Norton, 2002). Therefore, the derivative of the S data should also be obtained. This is obtained either from the continuous function of the S curve by the analytical derivative method or from the S data set by the numerical derivative method. The derived values used in this study are obtained by the numerical derivative method (Közkurt,2017).

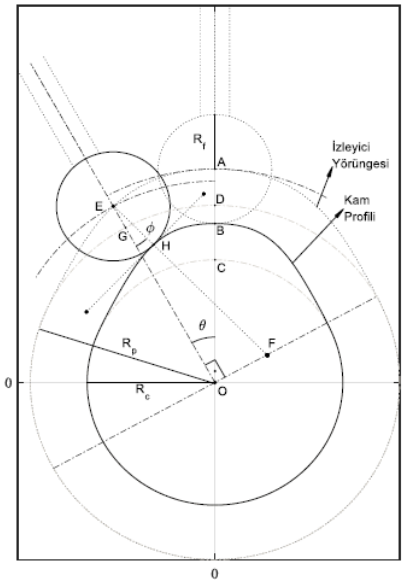

Figure 2.1: Round center follower cam mechanism analytical approach demonstration (Közkurt,2017).

It is seen that flat follower, translational cam mechanisms are generally used to control the gas exchange in the cylinder of the valve covers of internal combustion engines. In flat follower cam mechanisms, the orbit is formed on the cam surface. This situation makes the calculation a little easier. With the analytical approach in the literature, the cam profile geometry is obtained by using the base circle of the cam profile seen in Figure 2.2, the pressure angle and cam angle variables and the base circle radius constant (Közkurt,2017).

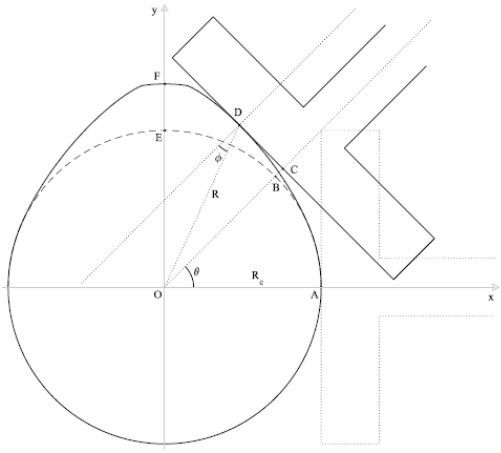

Figure 2.2: Straight center Follower cam mechanism analytical approach demonstration (Közkurt,2017)

The position of the tracker at each angle θ can be plotted on top of each other to obtain the envelope of the cam. However, obtaining the profile coordinates from the envelope of the cam may also require a numerical calculation. Figure 2.3 shows the envelopes of the cam plotted at different angle resolutions (Közkurt,2017).

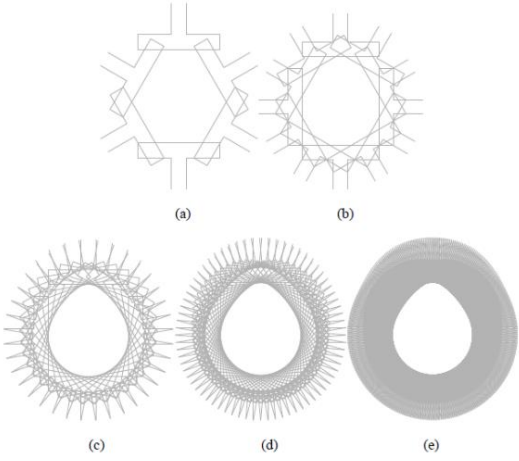

Figure 2.3: Flat Follower Cam Envelopes a)60 º b)30 º c)10 º d)5 º e)1 º (Közkurt,2017)

3. CAMSHAFT PRODUCTION WITH CNC GRINDING

The camshaft production process with CNC grinding machines has advantages such as mass production, surface roughness, less axis usage and therefore energy efficiency compared to the production process with CNC milling machines. In order to create a geometry that is not linear or circular in CNC machines, in addition to the linear and circular interpolation support offered by basic level CNC control systems, there should also be support for curve interpolation functions offered by high-level control systems. Curve interpolation commands are written by post-processor software that converts the wheel trajectory into NC codes in order to be run within the control systems. These codes are then loaded into the control systems and run to perform production on the CNC grinding machine. Brands that dominate the CNC manufacturer market for camshaft grinding, such as Schaudt and Junker, which manufacture CNC grinding machines for camshaft production, use Siemens' SINUMERIK series control systems. High-level curve fitting functions are also supported by CNC control system brands such as Heidenhain and Mazak. Polynom, Akima in CNC machines with SINUMERIK 840D, 840Di, 810D control system Spline, irregular rational B-spline (NURBS, Non-Uniform Rational B- spline) and Cubic There are functions for spline curves. These functions are used as POLY, ASPLINE, BSPLINE, CSPLINE respectively (Siemens, 2002). Spline functions are used to create a two or three dimensional curve. ASPLINE and CSPLINE are very similar to each other, but they obtain a smoothed curve passing through given points. BSPLINE is used to produce a curve when the coordinates of the control polygon of that curve are known, and despite its name, the operation is actually performed with NURBS curves (Közkurt,2017).

In a camshaft grinding system, the positions are obtained according to the angle with the movement of the wheel in the X linear axis and the circular movement of the C axis to which the camshaft is connected. In other words, the positions in the X axis according to the angle in the C axis form the cam profile. This system is similar to the cam mechanism, but the follower wheel does not get its position from the cam profile but from the servo motors of the X axis. Therefore, it is necessary to create a curve set for the X axis. However, since these curves must be continuous at the nodes, it is necessary to work with c- spline curves. Since c- spline curves consist of cubic polynomials, it is possible to calculate cubic polynomials in the postprocessor software and define them with the POLY function in the CNC control system.

CONCLUSION

In the SANTEZ study, which was carried out in cooperation with ESTAŞ AR-GE and Sivas CUMHURİYET UNIVERSITY Mechanical Engineering the mathematical methods and numerical operations required before the processing of high-speed flat and round centric follower radial camshafts used in internal combustion engines on Computer Numerical Control (CNC) grinding machines were presented. Obtaining the cam profile from the discrete data of the follower movement, obtaining the orbit data of the wheel that will process the cam with known profile coordinate data, expressing this data with numerical control (NC) curve interpolation commands were discussed in mathematical details and sample MATLAB® applications were implemented. A simulation software for the CNC grinding machine was developed for operator training using the MATLAB® commands obtained from the topics discussed.

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CHAPTER 3

POWDER METALLURGY

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INTRODUCTION

Today, with the developing industry, it is becoming important to be able to produce parts with high quality and working performance in one go without the need for machining. The mechanical, physical and chemical properties of a part play an important role in ensuring suitable and repeatable production continuity under working conditions. Powder metallurgy, which is a good alternative to part production with machining, serves a certain application area in the industrial sense in this respect (Roberts, 1984).

Powder metallurgy (PM) is a modern manufacturing method. It combines very small particles and turns them into a part. This process is a powder material technology that allows the mass production of small, complex-shaped workpieces that are difficult to produce with other production methods using metal powders (Benjamin, 1974).

Developed as an alternative to classical production methods, powder metallurgy has a widespread use in the industry due to the many advantages it provides. Many factors such as manufacturability, high efficiency and low cost make mass part production popular in powder metallurgy (Karagoz et al. 2009). Powder metallurgy production methods are developing day by day in our country as well as all over the world (Atas, 2003).

1.POWDER METALLURGY

The powder metallurgy production method is the pressing of powdered materials and sintering at high temperatures to transform them into the desired shape of parts. It was developed as an alternative production method to the chip removal and casting methods. With this method, parts that are difficult to manufacture are produced with low tolerance, high strength and very fast (Demir, 1992; Ünlü et al. 2009).

With the powder metallurgy method, self-lubricating bearings used in the automotive, aviation, defense industry, white goods and health sectors, automotive power transmission gears, position reader parts, machine parts, etc. can be produced (Bolay, 1998).

In our factory, in a closed area of 1500 m², in our pressing and sintering lines, parts suitable for customer requests are produced using iron-based, copper and bronze powders in accordance with the DIN 30910-4 standard.

1.1. Advantages and Disadvantages

Powder metallurgy is of great importance because it can easily, economically and serially turn various alloys that are difficult to produce with casting, machining and plastic shaping into products. When powder metallurgy is compared to other production methods, the following advantages are seen:

- The need for labor is low due to the high production speed.
- Complex shaped and precision parts can be easily produced.
- The physical and mechanical properties of the produced parts are quite high. The workability and tensile strength of the parts are high, and the grain size is small.
- When the material loss that occurs in casting and machining production methods is considered, a great deal of material savings is provided, and scrap losses are reduced.
- Additional processes such as machining are generally not required for parts produced with powder metallurgy.
- Scrap losses are reduced due to the speed of production, low labor and material loss, it is an economical production method.
- Due to differences in melting point and density, alloys or mixtures (composites) that cannot be produced by other methods can be produced.

In addition to the advantages mentioned above, TM also has some disadvantages as follows (Demir, 1992; Öztürk, 2015):

- According to some production methods, low mechanical properties can sometimes be obtained due to the presence of pores in the microstructure.
- The cost of the molds used for production is high.
- Part dimensions must be in the conditions determined by the press capacity. At the same time, there are limitations in part dimensions to obtain homogeneous densities.
- It is not an economical method unless mass production is done.
- Due to the uneven pressure distribution in the pressing operation, differences in density and mechanical properties can be seen along the part cross-section (Demir, 1992; Öztürk, 2015).

1.2. Powder Production Methods

There are generally four different powder production methods. These are: mechanical, atomization, chemical and electrolytic methods.

The powder we currently use is a method of obtaining powder by spraying liquid metal powder and blowing pressurized gas or water onto the sprayed metal. While powder properties can be controlled very well in atomization processes, the biggest advantage of the process is that it is suitable for alloy powder production. The sphericity of the powders is very good, and their compressibility is high (Höganas, 1996).

Iron alloy powders are divided into groups according to their production method and mechanical properties. The codes of the powders produced by HÖGANAS and the powders we have used in production are given below.

Table:1.1 Powder types of Höganas company

Sponge Iron Powders	**Atomized Iron Powders**	**Phosphorus Alloy Powders**	**Diffusion Alloy Powders**	**Prealloyed Powders**
NC100.24	AHC100.29	ABC100.30	Distaloy SA	Astaloy85 Mo
SC100.26	ASC100.29	PNC60	Distaloy AB	Astaloy Mo
MH80.23	ABC100.30	PASC60	Distaloy AE	Astaloy A
			Distaloy AF	Astaloy B
			Distaloy DC	Astaloy CrL
			Distaloy DH	Astaloy CrM
			Distaloy HP	

There are companies that produce powder in our country. These companies are:

- TMC Powder Metal,
- Güven Metal,
- Mxen Powder Metal and
- Sentes-Bir.

1.3. Powders Used in Estaş

Work begins with a detailed examination of the main images received from the customer. First, considering the hardness and density values of the mechanical properties of the material, the powders to be used in production are selected from the metal alloy powders belonging to the Höganas company. The powders are supplied by the company and the powder compositions are intervened in the powders specifically requested by consulting with the company.

The mechanical properties of the parts produced within our company are separated according to the properties of the powder codes specified in the DIN 30910-4 standard. Powders suitable for SINT C11, SINT D11 and SINT D32 standards can be used in the parts we produce according to the contact working conditions and desired mechanical properties.

The chemical compositions and mechanical properties of the SINT C11 and SINT D11 standard powders in the DIN 30910-4 standard are given below. In case parts with different properties are requested, the standard numbers of the powders to be used change

Table 1.2: Chemical and mechanical compositions of SINT C11 and SINT D11 according to DIN 30910-4 Standard

Abbreviation for Comp.	Density Value (g\cm^3)	Chemical and Mechanical Composition											
		By weight (%)								Tensile Force MPa	Yield strength MPa	Hardness	% Elongation
		C	Cu	Ni	Mo	Sn	P	Fe	Other				
C11	6,4-6,8	0,4-1,5	1-5	-	-	-	-	Kalan	<2	380-400	280-300	115	1
D11	6,8-7,2			-	-	-	-	Kalan	<2	450-470	360-380	130	2

The mechanical properties at fixed densities of 6.6 g/cm3 and 6.9 g/cm3 for both powder standards are given below. The density difference can be eliminated depending on the amount of copper (Cu) element used and the pressing force applied.

1.4. TM Production Method

1.4.1. Mixing the powder

Since powder mixtures are used in powder metallurgy, the powders must first be mixed effectively before the pressing process. The main purpose of the mixing process is to obtain a homogeneous powder mixture. Homogeneous mixing of powders of different shapes, densities and sizes positively affects the performance of the parts to be produced (Ulutaş, 2014).

When preparing powder mixtures, lubricants are added in certain proportions. The main purpose of adding oil is to eliminate or reduce energy losses that occur during pressing. Metal stearate such as stearic acid, zinc stearate, lithium stearate, calcium stearate and synthetic waxes are most commonly used as lubricants for metal powders (Ulutaş, 2014; Özgün, 2007).

In order to obtain a homogeneous mixture by adding to metal powders, the lubricant used must be mixed sufficiently with the powder. While under-mixed lubricants will not provide the expected properties; excessive mixing may also cause the lubricant with a low melting point to heat up and become sticky. Mixing time is an important factor in these cases (Ulutaş, 2014).

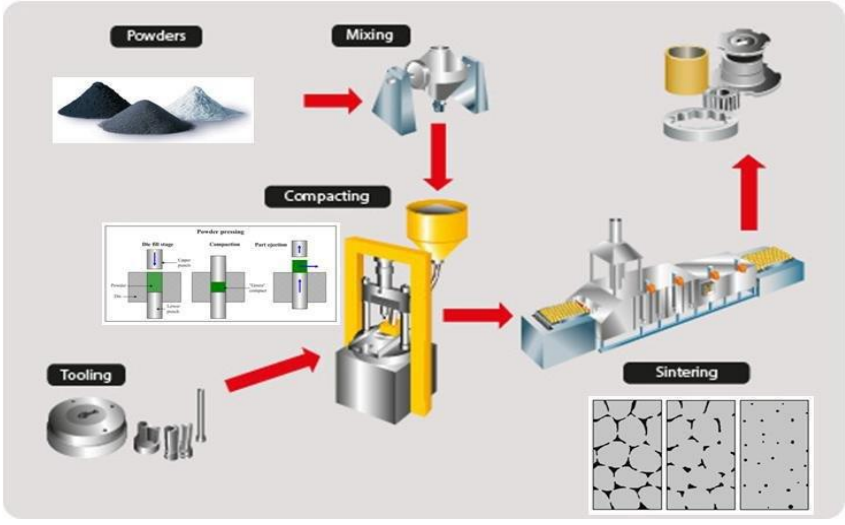

Figure 1.1: Powder metallurgy production stages (Tripathy et al. 2018)

1.4.2. Pressing

Powder metallurgy involves many processes to bring powders to a desired shape with a certain density level. The most common method of shaping TM parts is compression in uniaxial and biaxial molds.

In uniaxial pressing, the pressing force is applied in one direction. In biaxial pressing, the pressing force is applied in two directions. Powder particles are compressed in a rigid mold by applying pressure through the upper and lower punches (Acar, 2021). As the pressing pressure increases, the amount of voids and porosity decreases. The strength and density of the pressed sample also increases at high pressing pressure. Lubricants are used in the powder mixture to reduce the friction between the mold walls and the powder mixture during the process. After the pressing process, the sample is removed from the mold (https://uslularhadde.com/toz-metalurjisi).

Figure 1.2: Press bench used in powder metallurgy production

High compressibility is a primary factor in the production of parts made by pressing and sintering.

The pressing process generally consists of 4 main parts:

• Filling the mold with the required amount of powder mixture for delivery,

• Applying the pressing pressure to achieve the desired strength and density,

• Removing the upper punch from the sample,

•Removing the sample from the mold (https://uslularhadde.com/toz-metalurjisi).

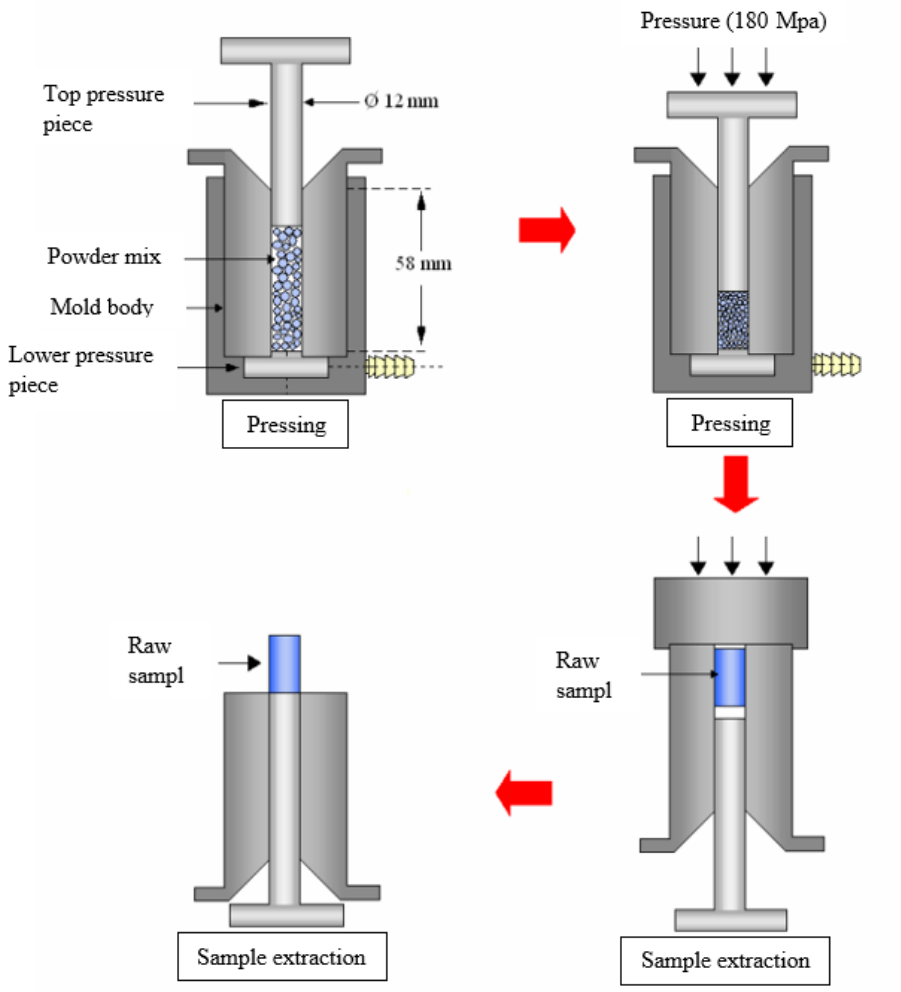

Figure 1.3: Schematic representation of the PM pressing method (Ulutaş, 2014)

1.4.3. Sintering

Sintering is a heat treatment method that allows particles to bond together at high temperatures. This process can be carried out by solid-state atom transport events at temperatures below the melting point, but can often

involve liquid phase formation (https://kocaelimakine.com/wp-content/uploads/2016/03/toz-metalurjisi-afsin-alper-cerit.pdf).

The sintering parameter of powders shaped in powder metallurgy is determined by the metal with the lowest melting point among the metals in the powder mixture. Sintering temperatures and times for some metals and alloys are given below.

Table 1.3: Sintering temperatures and times of some metals and alloys (Avci, 1993)

Powder Material	Sintering Temperature (°C)	Sintering Time (Minutes)
Bronzes	760-870	10-20
Brasses	843-898	10-45
Copper	843-898	12-45
Steel, Carbon Steels	1010-1148	8-45
Stainless Steels	1010-1148	30-45
Tungsten Carbides	1426-1482	20-30
Ferrite	1426-1482	10-600
Molybdenum	2054	120
Tungsten	2343	480
Tantalum	2398	480

The schematic representation of the pore structure, which starts with the point contact of the particles and changes during sintering, is given in the figure below. The void volume gradually decreases and the voids become more spherical. As void spherification occurs, the voids are replaced by grain boundaries (Öztürk, 2015).

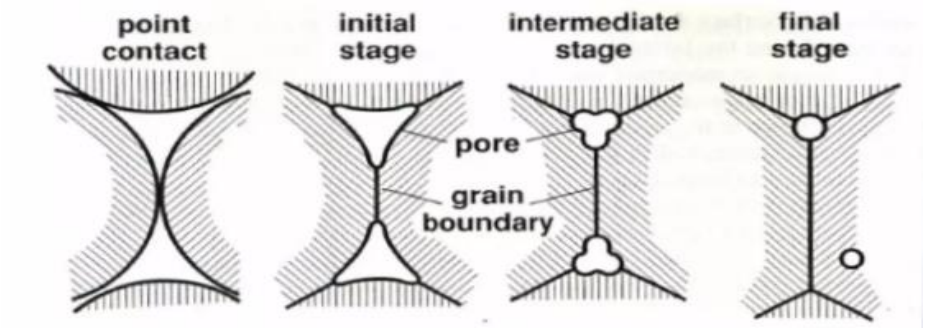

Figure 1.4: Schematic representation of sintering stages (German, 1994)

The schematic diagram of the oven we use in our factory's production line is given below.

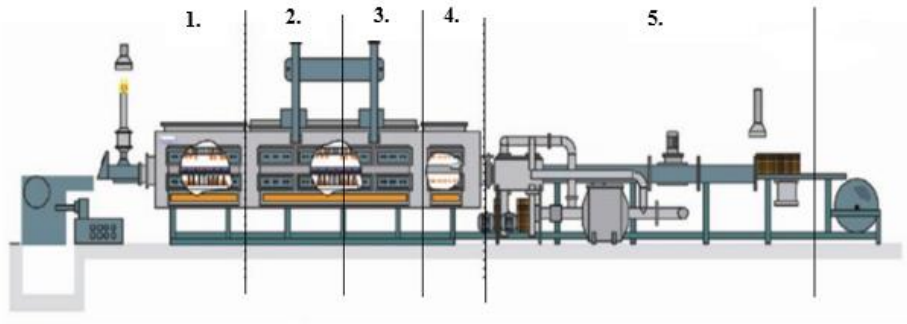

Figure 1.5: Sintering process regional distributions (Höganas, 2013)

- 1-2. zone preheating
- 3-4. zone sintering and
- 5. zone cooling.

The sintering process is carried out according to the following sequence of operations;

1) Furnace stage temperatures reaching the required temperature,

2) Adjusting the amount and ratio of gas given to the furnace,

3) Adjusting the loading belt speed,

4) Loading the parts into the furnace and

5) Removing the parts from the furnace.

1.5. Secondary Operations

Powder metallurgy components require properties that cannot be obtained by sintering alone. Secondary operations are applied immediately after the sintering process, depending on the area of use and on demand. These operations consist of processes such as second pressing, heat treatment, oil impregnation, deburring, machining, surface coating and infiltration (Çetinkaya, 2015).

Cementation and Induction: Secondary heat treatments (cementation and induction), which are part density and porosity reduction

processes, can be applied to obtain the desired mechanical properties in the products (Megep Malzeme vee Isıl İşlemler, 2011).

The cementation process is applied to low carbon steels. The steel surface is enriched with carbon. In the induction process, there is a mechanism that allows electric current to pass through the part via an induction coil. In this way, the material is heated to the desired temperature and then left to cool in a suitable cooling environment (Çavdar, 2019).

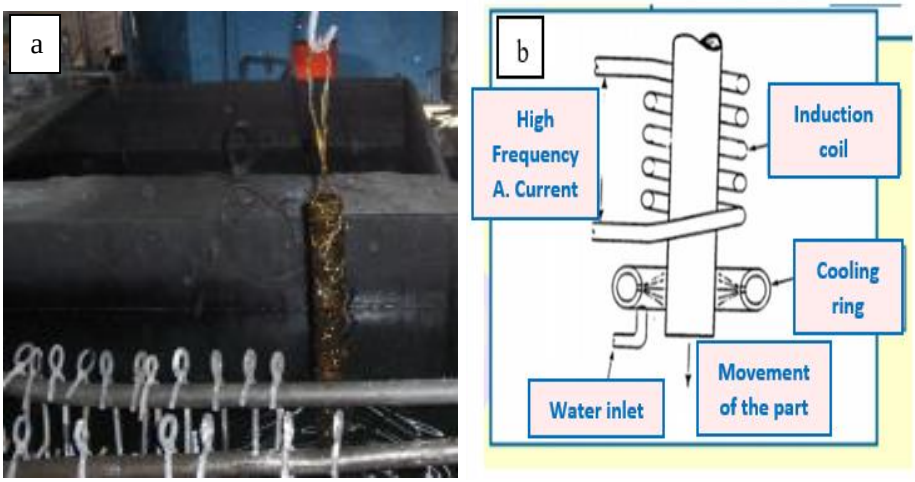

Figure 1.6: (a) Hardening by cementation (Megep Malzeme ve Isıl İşlemler 2011), (b) hardening by induction (https://www.ikielinduksiyon.com)

Oil impregnation method: It is an optional application where oil is impregnated in a way that fills the pores of parts containing 25-30% porosity. First, the air in the oil impregnation system is vacuumed and oil is impregnated and the vacuum is removed. At the end of this process, oil is impregnated into the micro pores of the parts. The parts produced with this method are generally called self-lubricating sinter bushings (https://uslularhadde.com/toz-metalurjisi). These bushings are:

- Self-lubricating,
- Maintenance-free,
- High precision,
- Low noise,
- High corrosion resistance,

• Can be used in many processes,

• Savings in material use and production (https://www.sinterteknik.com.tr/sinter-yataklarda-yaglama)

Our company has carried out sample studies of self-lubricating sinter bushings with A51 powder supplied by Höganas. The results obtained from the samples are positive. Our studies on bushings will continue.

Figure 1.7: Self-lubricating sintered bushings produced in Estaş

Machining method: Although parts with limited tolerance values and complex shapes are produced by sintering, these parts have dimensional measurements that cannot be obtained from pressing. Therefore, machining operations such as turning, milling, gear cutting are used. Machining is generally easier in sintered metals than in steel alloys (https://uslularhadde.com/toz-metalurjisi).

1.6. Control Of Mechanical Properties

1.6.1. Sintered Part Density Measurement

Density measurement is performed after the pressing process to control the production suitability of parts produced by the powder metallurgy method. The measurement method specified below can be applied to sintered and unsintered parts.

The measurement of compressed (unsintered) or sintered powder metallurgy parts is performed in accordance with the “Standard Test Methods for Density Using the Archimedes Method” standard.

The setup specified in Figure 5 is used for test samples. The samples to be measured must be at least 1.0 g For smaller parts, the measurement is performed by combining them and creating a minimum mass.

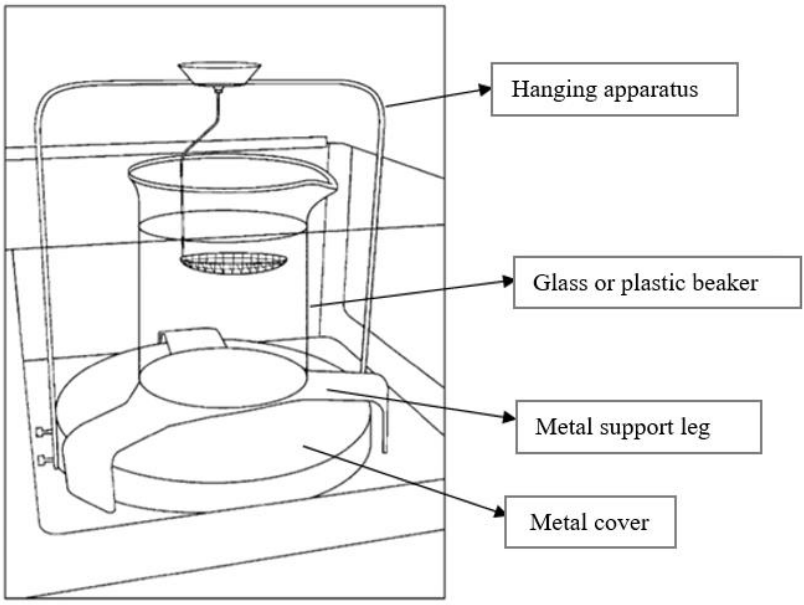

Figure 1.8: Schematic representation of the density measurement test setup

Table 1.4: Density values of water at 15-30 °C

Temperature		Density
°C	(°F)	g/cm^3
15	(59.0)	0.9991
16	(60.8)	0.9989
17	(62.6)	0.9988
18	(64.4)	0.9986
19	(66.2)	0.9984
20	(68.0)	0.9982
21	(69.8)	0.9980
22	(71.6)	0.9978
23	(73.4)	0.9975
24	(75.2)	0.9973
25	(77.0)	0.9970
26	(78.8)	0.9968
27	(80.6)	0.9965
28	(82.4)	0.9962
29	(84.2)	0.9959
30	(86.0)	0.9956

$$D = \frac{A\ x\ qsu}{(A-B)}$$

D = Density of the part (g/cm^3)

A = Weight of the part in air (g)

B = Weight of the part in water (g)

q_{su} = Density of water (g/cm^3)

1.6.2. Sintered Part Microstructure Control

Microstructure is called the very small-scale structure of a material (https://tr.wikipedia.org/wiki/Mikroyap%C4%B1). Materials produced by powder metallurgy are examined by magnifying them with an optical or electron microscope.

During the examination, images of different sizes are taken from different parts of the produced parts and care is taken to ensure that these images represent the entire microstructure. After the etching process is completed on the part, the etched surfaces are cleaned and dried, and made ready for examination under an optical microscope.

Figure 1.9: Optical microscope for microstructure examination

The microstructure controls of the sintered parts of the powder produced in accordance with the SINT D11 standard within Estaş are examined according to the prepared instructions. For example;

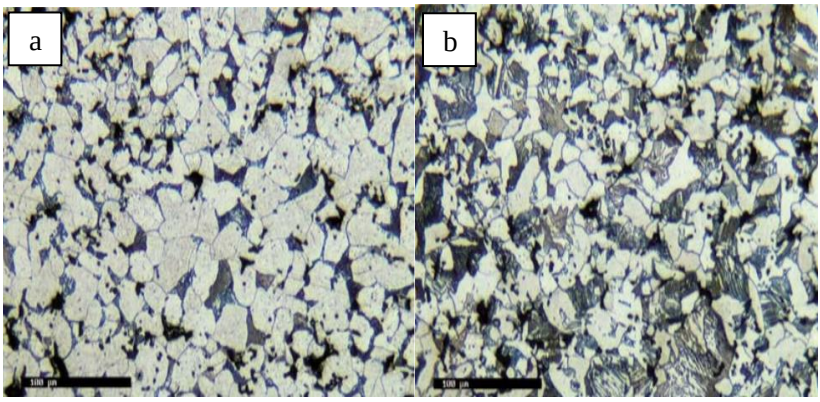

Figure 1.10: a) AHC 100.29+%0.2 C, b) AHC 100.29+%0.5 C, sintered part microstructure at 1120°C for 30 min (100x)

As can be understood from the figure, the structure consists of ferrite and pearlite phases. The increase in the amount of carbon in the powder increases the formation of pearlite (Erden, 2017).

1.6.3. Sintered Part Hardness Measurement

Hardness values of the parts produced with the powder metallurgy method can be measured with macro or micro hardness measurement methods according to the need. Hardness values are made with macro hardness measurement in our company.

The measurements to be made are made according to the conditions specified in the ISO 4498 standard.

Vicker, Brinell and Rockwell hardness measurement methods are used in macro hardness measurements. In the hardness measurement, the part is placed on a flat surface and the measurement is taken from the part surface without taking a section from the part. The surface to be measured must be clean and smooth in order to take accurate measurements.

Figure 1.11: Hardness tester

1.6.4. Sinter Part Fracture Test

This test, which is performed on the parts that have been produced, provides the part with values close to its real stress mode and the detection of internal cracks that may occur in critical areas in its raw state under a certain force.

The parts to be tested consist of finished parts with all processes completed.

Unless otherwise stated, the test to be applied is used to determine the average, standard deviation, minimum and maximum values. There is no value in the literature or standards that can be compared with the fracture resistance.

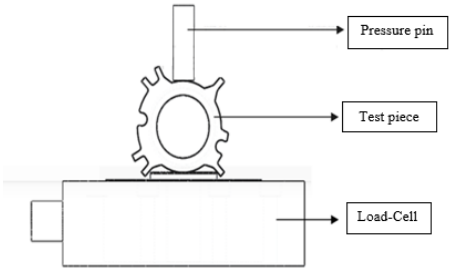

Figure 1.12: Schematic representation of the placement of the part in the mechanism for the fracture test.

1.6.5. Sintered Part Tensile Test

The measurements of the tensile test sample used in the tests are made according to the ASTM B925 standard. The dimensions of the part are given in Table 5.

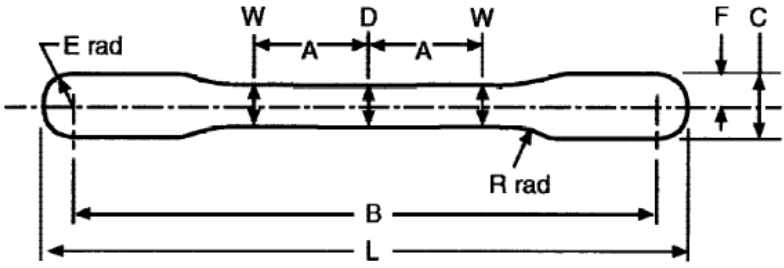

Figure 1.13: Schematic representation of the tensile test test piece.

Table 1.5: Tensile test sample dimensions

	in.	mm
A—Half length of reduced section	0.625	15.88
B—Grip length between centers	3.187 ± 0.001	80.95 ± 0.03
C—Width at grip section	0.342 ± 0.001	8.69 ± 0.03
D—Width at center	0.225 ± 0.001	5.72 ± 0.03
E—End radius	C/2	C/2
F—Half width at grip section	0.171 ± 0.001	4.34 ± 0.03
L—Overall length	3.529 ± 0.001	89.64 ± 0.03
R—Fillet radius	1.00	25.4
W—Width at end of reduced section	0.235 ± 0.001	5.97 ± 0.03

The tensile test is performed on the Alşa brand tensile test device located in the factory.

The values obtained from the tensile test are compared with the tensile, yield and elongation values specified in the standards to confirm the conformity of the parts.

1.6.6. Sinter Part Crack Control

Crack controls of sintered and unsintered powder metal parts are performed by our company with a magnetic particle crack control device.

Figure 1.14: Magnetic particle crack control device

The magnetic particle crack control device mostly examines surface cracks. The circular magnetic field is applied by passing current through the part; the linear magnetic field is applied with an electromagnet. Magnetic fields are applied simultaneously, allowing the cracks in all directions to be viewed (https://www.tmmndt.com/pinollu-catlak-kontrol-cihazlari).

There are many factors that can cause cracks in parts in TM production. To give examples of these:

- Asynchronous compression,
- Excessive and insufficient force,
- Too high density,
- Too low density,
- Unwanted taper on the die face,
- Due to misalignment of the dies,
- Asynchronous die movements,
- Uncontrolled die movements,
- Due to part geometry,
- Wear of the die parts and
- Bad tool surfaces.

CONCLUSION

ESTAŞ, a supplier of the world's leading automotive brands, is a company that constantly renews itself with new technologies for customer satisfaction, uses its resources efficiently and effectively, and produces quality products with creative solutions. It continues this development in the field of powder metallurgy with formations that will meet the needs of different sectors.

ESTAŞ has carried out many studies and projects in the field of powder metallurgy. The projects that have been carried out and continue to be carried out in this field are given below.

- **Production of camshaft sensor of EC5 engine by powder metallurgy method and assembly to camshafts**

Due to reasons such as the fact that the production by machining takes a long time and the time spent on the product obtained as a result of various operations, production by powder metallurgy has become more advantageous.

- **Making product, mold and process designs for the production of self-lubricating sinter bushings and production by powder metallurgy method**

Bushings in the market are used in various sectors. Since the number of manufacturing companies is limited, it is aimed for our company to take place in this sector.

- P**roduction of 03L gear set by powder metallurgy method**

It is foreseen that the gear group targeted to be produced within the scope of the project will be produced much faster and much less costly than machining in line with the needs of our company.

- **Comparison of mechanical properties of FLC4908 and SintD32 materials used in the same process conditions on the final product**

Studies were conducted to determine the effects, advantages and disadvantages of materials in the same process conditions on the product.

These projects have been completed positively and have begun to be commercialized. New work will continue in line with customer demands.

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CHAPTER 4

ESTAŞ GLOVE TECHNOLOGY

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INTRODUCTION

With the discovery of the HIV and AIDS viruses that caused cross-contamination in the 1980s, the emergence of contamination measures has led to the widespread use of latex gloves, which are natural rubber, in medicine and dentistry, as they reduce the risk of infection (Mew, 2015).

Today, the use of gloves in dental surgery is necessary to prevent the transmission of diseases due to needlesticks and injuries and blood transfer (Clarke, 2004).

In addition, gloves are important in the treatment of diseases because they protect the skin against chemical substances (Critchley & Pemberton, 2020).

Historically, latex gloves have been found to be more useful in terms of dexterity (Critchley & Pemberton, 2020). However, it has been stated that the most common allergy in dentistry is latex allergy (Baran & Nalçacı, 2007).

A study conducted on primary care dentists in 2000 found that 87% of dentists wore latex-containing gloves and 11% wore latex-free gloves (Burke et al., 2005). A similar study repeated on primary care dentists in 2008 showed that 81% of dentists wore latex-containing gloves and 19% wore latex-free gloves (Brunton et al., 2012).

A similar study conducted in 2015 concluded that there was a radical change in the glove material used, with latex glove use decreasing to 25% and 75% wearing latex-free gloves (Burke et al., 2019).

The results of a survey conducted in 2017 confirmed that latex glove use had decreased (Critchley and Pemberton, 2020).

1. THEORETICAL KNOWLEDGE

1.1 Glove Definition

Gloves are generally disposable materials used to prevent cross-contamination between patients and doctors, caregivers, nurses, etc. during medical examinations. They also meet the requirements of both directives as they are used as both personal protective equipment and medical devices.

For this reason, gloves are manufactured in accordance with the TS EN ISO 13485:2016 Standard, the (EU) 2017/745 Medical Device Regulation and the EU 2016/425 Personal Protective Equipment Regulation (Mellström and Carlsson, 1994).

- Protective gloves are classified into three categories, depending on the purpose of use and approval procedures, as given in Table 1.1:

Table 1.1 Types of Gloves Used as Personal Protection (Mellström and Carlsson, 1994)

Category level	Use
Category I	- These are simply designed gloves used in minimum risk applications. - Disposable and/or reusable gloves for wet work that protect against cleaning agents and surfactants in the home and workplace. - For the CE marking, the gloves and the packaging must contain the following text: "Only for minimal risk." No testing of the protective effect is required.
Category II	- Mid-level design gloves for medium risks, neither simple nor complex in design - Should be used when there is minimal or no high risk. - For the CE marking, the protective effect must be tested and approved by a certified laboratory. It must also be labeled with the CE marking and a pictogram (symbol)
Category III	- For high risks, gloves with a more complex design - Gloves must be tested for intended use by a certified laboratory. - Gloves/packaging must be labelled with the CE mark and a pictogram (symbol) indicating the protective performance for a specific risk and the four-digit code of the certified laboratory that performed the testing.

For categories II and III, there are additional requirements for EC inspection tests carried out by approved laboratories, certified by approved bodies, and production within the scope of an official EC quality assurance system.

The European Standard for protective gloves, which defines the general requirements for most types of protective gloves, is EN 420. Some of the EN and ASTM Standards for chemical protective gloves are given in Table 1.2 below. (Mellström and Carlsson, 1994).

Table 1.2 EN and ASTM Standards for Chemical Protective Gloves (Mellström and Carlsson, 1994).

Standard	Standard Title
ASTM D 3577	Standard Specification for Rubber Surgical Gloves
ASTM D 3578	Standard Specification for Rubber Examination Gloves
ASTM D 5151	Standard Test Method for Detecting Holes in Medical Gloves
ASTM D 5250	Standard Specification for Poly(vinyl chloride) Gloves for Medical Application
ASTM D 5712	Standard Test Method for Analysis of Aqueous Extractable Proteins in Natural Rubber and Its Products - Using the Modified Lowry Method
EN 455	Disposable Medical Gloves
• 455-1	Hole-free (Leak-tight) Test
• 455-2	Requirements and Tests Regarding Physical Properties
• 455-3	Requirements and Tests for Biological Assessment
• 455-4	Requirements and Tests for Determining Shelf Life

1.2 Glove Types According to Their Structure

1.2.1 Latex Gloves

Latex is a natural type of rubber. This type of rubber, which is frequently used in our daily lives, is used as an inseparable part of our lives and is estimated to be used in approximately 40,000 types of products today (Cronin, 1980; Görücü Coşkuner and Kocadereli, 2015).

Natural rubber latex is exuded by making cuts in tree bark (Cabañes and ark., 2012), produced from the tropical tree Hevea brasiliensis (Critchley and Pemberton, 2020) It is a milky watery liquid that has a thicker and more

durable structure when it comes into contact with air (Figure 1.1) (URL-1) (Cabañes et al., 2012). This is an effect of rubber milk.

There are many natural substances in latex such as protein, sugar, oil, gum, tannin, resin, starch and alkaloid. Although latex gloves are generally white due to the latex rubber in their structure, they are also produced in different colors such as yellow, red and orange by using dye during production. Since the structure of the rubber is quite flexible, the gloves produced help to feel the surface completely and ensure that the tools and equipment to be used during the examination are used comfortably. It prevents unwanted substances such as diseases, dirt, microbes and viruses from being transmitted to the person using it. It is available in 2 types, both powdered and powder-free, in order to ensure that people with sensitive skin can use it comfortably. (URL-1).

Figure 1.1 Hevea Brasiliensis Tree (URL-1)

Natural latex has many uses in many areas because of its elasticity, flexibility, low cost, biocompatibility, and ability to promote and accelerate angiogenesis (Balabanian et al., 2006; De et al., 2019) and has emerged as a new material due to its contribution to tissue repair and angiogenic potential (Issa and al., 2021). In addition, the use of the protein fraction obtained from this rubber has enabled the formation of new vessels (Ferreira et al., 2009).

Latex is also used in medical gloves. The most important purposes of its use in medicine are its durability, not causing loss of touch sensitivity, flexibility and ease of wear, and comfort during work. For this reason, it is often preferred by doctors. However, skin irritation, redness and latex allergy that may develop during use can be counted among its undesirable properties

(Yuluğkural, 2011). Latex (or natural elastics); consists of cis-1,4 poly-isoprene chains with many preservatives, usually ammonia, added to its content in order to obtain properties such as elasticity, flexibility and durability (Perrella and Gaspari, 2002).

Latex gloves, which are still widely used today due to their high flexibility and low cost (Kanchana and Godfrey, 2000), are industrially produced by containing a mixture of natural rubber with stabilizers, especially Zinc Oxide and other chemicals (Martinez-Colomer et al., 2016).

Areas of Use of Latex in Dentistry

Latex is used extensively as a dental material in dentistry, where cytotoxicity problems are also common (Fiddler et al., 1992). It is known that preservatives such as sulfur and zinc oxide, as well as antioxidants such as di-thio carbohydrates, N-nitrosodibutylamine and N-nitrosopiperidine, which are added to the structure of latex, are all cytotoxic substances (Hwang and Cha, 2003).

In addition, sulfur, which is added to the structure of latex gloves during the vulcanization process, interacts with the catalytic regions of other added silicone materials and prevents the polymerization of silicone. For this reason, controlled use is required (Machado and Guedes, 2011).

What are the Advantages of Latex Gloves?

- Due to their flexible structure, they can be easily put on and taken off during the examination.
- One of the biggest benefits it offers to doctors is that since they do not prevent surface sensitivity, doctors can easily perform any procedure they want without difficulty thanks to latex gloves since they use many different health tools during the day.
- It does not cause any harm to the skin of users due to its anti-allergic structure.
- It offers the opportunity to use it without powder for people with skin sensitivity, with powder for those without, and offers 2 types, both powdered and powder-free, among its other benefits (URL-1).

Latex allergy:

- The use of latex gloves may cause undesirable reactions such as irritant contact dermatitis, skin rash, papules, drying, redness, flaking and cracking.
- Type IV hypersensitivity, which occurs with eczema 48-96 hours after contact, is another undesirable reaction. The main cause is chemicals used in glove production such as carbamates.
- Type I hypersensitivity, latex protein allergy, is a serious undesirable effect that can cause regional residue, burning, discomfort, rhinitis, urticaria, and even asthma attacks, and rarely, anaphylaxis within 5-60 minutes (Yuluğkural, 2011).

Type I hypersensitivity is less than 1% in the general population, but there are some risk groups where higher rates are seen. Healthcare workers are in this risk group and the rate of occurrence is stated as 2.8-16.9%. The user's medical history is an important situation to be considered in this regard. The skin test that can be applied can reveal the allergen and the response that will develop in case of exposure to it.

The wisest way in the presence of latex allergy is to avoid latex proteins and use products that do not contain it (Yuluğkural, 2011).

1.2.2 Vinyl Glove

Vinyl gloves, which do not contain natural latex and are made of a material called polyvinyl chloride (PVC), are known for their white color and are the most common gloves in the sector with the advantages of not containing powder, not causing redness, itching and wounds on the hands, and being quite economical in price (URL-2).

Vinyl gloves are preferred by people with allergies, especially due to the substances they contain, compared to latex gloves. Therefore, it is recommended that those with sensitive skin use vinyl gloves. They are frequently used by healthcare professionals in hospitals to protect themselves from contamination risks in the hospital environment. Since vinyl gloves contain many chemicals to prevent allergies, long-term use damages the skin, so it is not recommended because it will create a risk when our skin comes into contact with these chemicals too much. Therefore, vinyl gloves are

designed for single use. Therefore, they should not be used for a long time, they should be thrown away after use and a new one should be worn (URL-2).

These features make vinyl gloves ideal for use in medical device manufacturing, microelectronics and similar dry controlled environments. They fit more comfortably on the hands of workers in the production area than latex or nitrile.

Among its advantages are its affordability, comfort, softness and not containing latex. However, it provides standard protection and its disadvantages are its low durability and its decrease in sensitivity in jobs requiring precision. For this reason, it is not suitable for use in high-risk, hazardous situations and processes that require chemical contact (Yuluğkural, 2011).

1.2.3 Nitrile Glove

Nitrile gloves are gloves that contain nitrile butadiene rubber (NBR), a synthetic rubber type, in their structure. Since it is synthetic rubber, it does not contain protein and powder in its structure. Therefore, it is recommended that people who are allergic to protein use nitrile gloves and are suitable for use in areas where gloves are constantly used, such as laboratories, where they will irritate the body. In addition, it provides much higher chemical resistance compared to latex and vinyl gloves, as well as flexibility and a soft touch (Yuluğkural, 2011).

Latex is produced from organic tree sap and contains proteins that are considered allergenic by the FDA, while Nitrile is produced from a 100% inorganic synthetic material. Its durability is 2 to 3 times greater than latex gloves (Yuluğkural, 2011; URL-2). The rough fingertips found in nitrile gloves allow for a full grip on the touched area. Although it is usually produced in blue, there are also alternative colors such as orange and black (URL-2).

- **What is the Difference Between Nitrile Gloves and Vinyl Gloves?**
  - Nitrile gloves are quite durable compared to vinyl gloves thanks to their durable structure.
  - Nitrile gloves provide maximum adhesion on the surface thanks to their rough fingertips.
  - Nitrile gloves are more resistant to chemicals than vinyls.

• Nitrile gloves are more durable than vinyls and provide long-term continuous use (URL-2).

- **What is the Difference Between Latex Gloves and Vinyl Gloves?**
  - Latex gloves are much more flexible than vinyl gloves thanks to the natural rubber they contain. Therefore, they are easier to put on and take off. However, vinyl gloves are more durable.
  - Since latex gloves come in two types, powdered and powder-free, it is recommended that people with allergies use either the powder-free type or vinyl gloves.
  - Latex gloves have a more natural structure compared to vinyl gloves, and vinyl gloves are not suitable for long-term use due to the chemicals they contain.
  - Latex gloves have a higher surface sensitivity due to their flexible structure. Therefore, they are easier to use (URL-2).

- **What is the Difference Between Latex Gloves and Nitrile Gloves?**
  - Nitrile gloves have a more durable structure than latex gloves and provide better grip thanks to the rough surface on the fingertips.
  - Nitrile gloves are recommended for people who are allergic to protein (URL-2

NITRILE GLOVE

LATEX GLOVE

VINYL GLOVE

Glove selection according to their features is shown in Table 1.3.

Table 1.3 Glove Selection Based on Features

GLOVE SELECTION TABLE			
	VINYL	LATEX	NITRILE
Static Dissipation	+++	-	+++
Protein Allergy	No	-	No
Chemical Resistance	-	++	+++
Strength / Durability	+	+++	++
Module	-	++	+++
Tactile Sensitivity	-	++	+++
- Weak	+ Good	++ Better	+++ Very Good

1.3 Glove Types According to Their Use

1.3.1 Examination Glove

Medical examination gloves are used worldwide and are one of the most widely used personal protective equipment (PPE). The polymers used to develop these gloves undergo rigorous testing to ensure they meet the requirements for use. These tests primarily evaluate barrier integrity and tensile properties (Preece, 2021).

The purpose of medical examination gloves is to act as first-line personal protective equipment (PPE) to protect hands from contamination. The demand for gloves has increased due to the rise in the SARS-CoV-2 (covid-19) pandemic, with gloves being worn more frequently and replaced more frequently (Anedda et al., 2020).

However, the effects of placing a membrane over the hand have been shown to be detrimental to the successful performance of tasks performed by the user. It is unknown how much this performance is reduced, but any reduction in tactility and/or dexterity may be disadvantageous to patient care. It may also impact PPE compliance by requiring users to remove their gloves for certain tasks (Preece, 2021).

1.3.2 Surgical Glove

Surgical gloves are similar to examination gloves, but are available in more precise sizes and are said to provide better tactile sensitivity (Preece, 2021). They also have certain characteristics such as thickness, elasticity, and resistance and are included in medical gloves (URL-3).

During surgeries, gloves have been used to protect surgeons' hands from injuries and infections. One of the purposes of the first use of surgical gloves was to protect the patient from infection and to protect the doctor's and staff's hands from chemical solutions that reduce the risk of infection (Ellis, 2008). The purpose of use has been shaped over time according to social life, disease conditions, and the area needed, and the main purpose of use has become to reduce the risk of infections such as surgical site infections in patients caused by the flora on the hands of healthcare workers and to protect healthcare workers (URL-4).

1.3.3 Chemotherapy Glove

Chemotherapy gloves are thicker to prevent radiation from quickly penetrating the skin (Preece, 2021). They are usually made of nitrile. They usually have the same chemicals as nitrile examination gloves as raw materials. The gloves are made thicker to be more permeable to drugs. Nitrile gloves that have been tested for permeability to chemotherapy drugs can also be used as chemotherapy gloves after passing the test.

1.3.4 Antistatic Glove

Antistatic gloves, which are used against the harmful effects of static electricity, are frequently used in areas such as the electronics sector, laboratories, electrical work in the biotechnology field, clean rooms and the automotive sector. Antistatic gloves do not produce static charge because their surface resistance values are lower than normal gloves (URL-12).

1.3.5 Sterile Glove

Hygiene is very important in almost all professions. This issue is of great importance especially in surgical operations and sterile gloves should be used in addition to normal examination gloves. In this way, patients are prevented from contracting diseases due to external effects (URL-13).

Sterile gloves are a type of glove that has been purified from microorganisms through special processes. The same care is taken in packaging and double-layer packaging is done to prevent exposure to external effects. It can be produced from different materials depending on the purpose of use. Latex, synthetic and similar materials are suitable for sterile gloves. They also have various numbers depending on the hand type. There are

powdered and powder-free varieties. Surgical gloves are mostly used sterile (URL-13)

Healthcare workers must wear sterile gloves when touching the patient's mucosa, areas of the skin that have been damaged due to cuts, scratches, wounds and burns, and during any procedures where the patient comes into contact with the skin using any surgical instrument (Thomas, 2009).

1.4 The Importance of Gloves in Health

Healthcare workers, who are exposed to biological, chemical and many other hazards and risks in the environment they work in (Beşer and Topçu, 2013; Pakdemirli, 2021), take risks for both themselves and their families by touching biological waste belonging to patients, touching surfaces contaminated by these wastes and medical supplies used and contaminated by patients, and also by having to breathe the air that patients breathe. In order to protect both themselves and their families, they need to take additional protective measures to reduce this high risk to more minimal levels (Pakdemirli, 2021).

It is important to protect the health of healthcare workers, as infectious microorganisms in the work environment, work accidents resulting from working with cutting and piercing tools, extremely hot or cold working conditions, long hours of work, a noisy work environment, poor lighting and ventilation can be listed among these risks.

It is very important to use personal protective equipment (PPE) that will provide protection according to the type of microbial agent in chemical, biological, radiological and nuclear incidents that can cause injuries and deaths. Therefore, which protective equipment should be used in which area should be applied by people who have received specialized training in the field (Pakdemirli, 2021). Because a negativity experienced in the workplace not only affects the safety of healthcare workers, but also affects productivity by reducing motivation (Zenciroğlu, 2011).

Choosing the right PPE is very important to protect people from hazards affecting the respiratory system, skin, eyes, face, hands, feet, head and body in chemical, biological and radiological emergencies. However, it is not possible for a single protective equipment to provide protection against all

risks. For this reason, it should be used with different equipment according to the instructions for use (Antosia et al., 2006; Chughtai et al., 2019).

- **PPE Levels:**

In order to provide a high level of protection with the PPE used by healthcare personnel in the diagnosis and treatment of patients in order to reduce the risk of contamination, it is necessary to provide not only a single PPE use but also respiratory, eye and face, hand and foot and body protection. The purpose of using PPE is to protect or isolate individuals from possible chemical, physical and biological hazards in a dangerous situation (Pakdemirli, 2021).

- **A Level PPE**

- Level A PPE is used in situations where respiratory, skin, eye and mucosal protection must be at the highest level.
- These are the equipment used to protect the respiratory system, skin, eyes and mucosal membrane of the personnel at the highest level in environments where there is a radiological and nuclear agent, if the type and concentration of the agent are unknown.
- Level A PPE may include a positive pressure breathing apparatus with a full face mask, a fully impermeable, vapor-tight protective suit, inner and outer gloves, and boots.
- In high-risk situations or suspicious situations, level A PPE provides high protection for personnel (Sezigen and Kenar, 2019).

- **B Level PPE**

- Level B PPE is used in cases where the type of radiological and nuclear agent in the environment is known but its density is unknown, and respiratory protection is at a high level but skin and eye protection is at a low level.
- The difference between level B and level A equipment is related to the characteristics of the protective equipment. Level B equipment is made of permeable material (Pakdemirli, 2021).

- **C Level PPE**

- If the type and amount of microbial agent is known and the probability of skin or eye exposure is low, level C PPE should be used. These equipment are suitable for use by healthcare professionals during the treatment of patients who are contaminated or in situations that do not require high protection after treatment, provided that the air in the environment is periodically monitored.
- Full or half-face air-purifying masks, protective clothing against chemicals, gloves, boots and face shields resistant to internal and external effects can be given as examples of level C PPE.
- Level C PPE provides the same degree of skin protection as level B equipment but less respiratory protection.
- Level C PPE is also recommended to be worn in the treatment of radiation injuries resulting from external or internal contamination (Pakdemirli, 2021).

- **D Level PPE**

  - Level D PPE is the least protective material. Examples include aprons, gloves, surgical masks, glasses and face shields (Pakdemirli, 2021).

1.4 Usage Areas of Gloves

Among the glove types, latex gloves are the most widely used and are preferred by healthcare workers to prevent hospital infections, and by users outside the healthcare field to prevent direct contact with harmful substances such as dirt and germs in food, and to prevent damage to hands during cleaning.

- **Lateks gloves are generally;**

  • Cooks
  • Veterinarians
  • Doctors and nurses

- Professional groups involved in food production and distribution
- Painters
- Hairdressers
- Used by all professions where no permanent substance is desired to be contaminated on the hands.

Nitrile gloves, which are the most durable type of gloves, have a higher grip capacity thanks to their rough fingertips. This makes them more grip-able than others.

Therefore;

- Surgeons
- Chemists
- Laboratory Technicians
- Those who do chemical cleaning usually prefer this glove.

In addition, it is also suitable for use in other areas where latex is used.

Vinyl gloves are also made of artificial rubber like nitrile gloves and are not as durable as nitrile gloves. Since they are powder-free, they are preferred by those who are allergic to powder and latex.

1.5Nitrile Examination Glove Standards

According to the inspection and surgical glove standards managed by the US Food and Drug Administration (FDA), gloves must meet higher quality standards. Manufacturers must manufacture by taking into account the standard requirements (URL-6).

European Norm (EN) standards specify minimum performance requirements and test methods for many products, including personal protective equipment in Europe (URL-7).

Below are some EN and ASTM standards for nitrile examination gloves:

- EN 420 standard is a reference standard for other standards in the production of protective gloves and covers glove design and manufacturing, usefulness, general requirements for comfort and

efficiency, relevant test procedures and markings and information provided by the manufacturer for all protective gloves (URL-5).

- EN 374-5 standard covers the requirements for gloves that provide protection against bacteria, fungi and viruses.
- Protective gloves against microorganisms must pass the permeability test according to the EN 374-2 standard (URL-8). EN 374-2 standard is a test method for determining the resistance to permeability of gloves that provide protection against chemical substances and microorganisms.
- In our country, the Turkish Standards (TS) EN 455-1 standard covers the hole-free test method for disposable medical examination gloves (URL-9). According to the standard, 1 liter of water is poured into the gloves and checked for holes. The standard states that the acceptable quality level (AQL) for examination gloves should be 1.5. The AQL determines how many of the gloves are defective (Yuluğkural, 2011). Medical gloves are important for easy wearing and good grip on the hand, as they affect the success of the process (URL-10, URL-11).
- The TS EN 455-2 standard covers the properties and physical tests of disposable surgical and examination gloves used to adequately protect the user and patient from cross-contamination.
- The TS EN 445-3 standard covers the properties and tests for biological assessment. Tests are performed to understand the levels of chemical residues left on the glove during production and the levels of latex protein in the glove. The standard states that the powder level for each glove should be a maximum of 2 mg (URL-9).
- ASTM D6319: Standard technical specification for nitrile examination gloves.
- ASTM D6124: Standard test method for residual powder on medical gloves.
- ASTM D5151: Standard test method for hole detection for medical gloves.

- ASTM D412: Vulcanized rubber and thermoplastic rubber and thermoplastic elastomers-Test methods for tension.
- ASTM D573: Test method for rubber-deterioration.
- ASTM D3767: Rubber size measurement (Yuluğkural, 2011).

1.6 Physical Properties of Gloves

The breaking force (N) of gloves is measured as a physical test under the EN 455-2 standard. The standard specifies that the breaking force values should be at least 6 for examination gloves and at least 9 for surgical gloves.

According to the ASTM D 6319 standard within the scope of the American Testing and Materials Standardization (ASTM), tensile strength (MPa = megapascal) and % elongation (% = change in size / main size) values are measured as physical tests. According to the ASTM D 6319 standard, tensile strength for examination gloves should be at least 14 and % elongation should be at least 500.

In a study conducted using ASTM, vinyl gloves showed poorer physical properties than latex and nitrile gloves in terms of tensile strength, % elongation and finger thickness (mm = millimeter) (Rego and Rolley, 1999).

In order for dental gloves to fulfill their protective function against infections, they must be made of chemicals that will create an impermeable barrier against potential pathogens. However, many dental materials negatively affect the structure of gloves. Dental materials with a solvent effect increase the permeability of gloves and thus increase the risk of infection (Zortuk, 2009).

Acids, tooth whitening agents, acrylic monomers, and chloroform are reported as substances that increase the permeability of gloves (Hunt et al., 1995).

According to a study, contact of orange solvent with latex gloves for a period of 15 minutes increases permeability more than washing the gloves with soap and water (Zortuk, 2009). In addition, washing the gloves and using them for more than 3 hours also causes the barrier functions to deteriorate (Oztan et al., 2007).

1.7 ESTAŞ Glove Factory Current Production Line

The main chemicals used in production are given in Figure 1.2, and images related to production are given in Figure 1.3, Figure 1.4 and Figure 1.5.

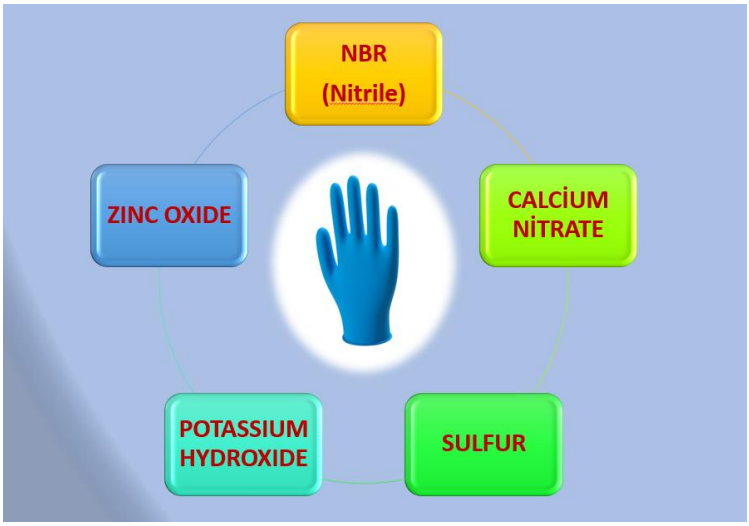

Figure 1.2 Main Chemicals Used in Glove Construction

Figure 1.3 Dipping of Ceramic Glove Molds into Chemicals

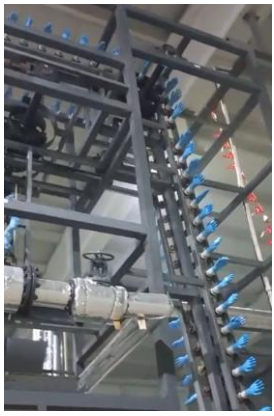

Figure 1.4 Drying of Chemically Immersed Molds in Ovens

Figure 1.5 Removing Gloves from Molds

1.8 Technical Specifications of ESTAŞ Glove

Technical specifications of Estaş Gloves are given in Table 1.4.

Table 1.4 Glove Product Identification

PRODUCT IDENTITY	
Product Category	**Medical Device Regulation (EU) 2017/745 Class I, Regulation 1**
	Personal Protective Equipment Directive (EU) 2016/425 Category III
Size	**S, M, L, XL**
Product Name	**Non-Sterile Powder-Free Nitrile Examination Gloves**
Material	**Nitrile**
Powder	**Powder-free**
Sterility	**Non-Sterile**
Approval	**MD / PPE / FDA**

1.9ESTAŞ Glove Product Description

Quality standards for ESTAŞ Gloves are given in Table 1.5, and product features are given in Table 1.6.

Table 1.5 Glove Quality Standards

QUALITY STANDARDS			
Feature	Final Product	Output Standard / Standard Name	Explanation
Material	Synthetic Nitrile Rubber (NBR)	ASTM D6319-19:2023 / Standard Specification for Nitrile Examination Gloves for Medical Applications	Gloves are made of nitrile raw material.
Powder Condition	Powder free	EN 455-3:2023 / Biological Evaluation of Disposable Gloves – ASTM D6124:2022 / Standard Test Method for Residual Powder on Medical Gloves	The total powder residue in the glove has been proven by tests that the amount of powder does not exceed 2 mg per glove, and it is classified as powder-free.
Migration	Suitable for contact with food	EN 1186 / Articles and Materials Intended for Foodstuffs - Plastics	Migration tests have proven its suitability for food contact.
Labeling	Box packaging	ISO 15223-1:2021 / Information Provided by the Medical Device Manufacturer - Symbols to be Used with Labels, Marking and Information for Medical Devices	Symbols that meet the specifications and manufacturer information of the final product have been used in accordance with the standard.
Storage Conditions	Store in a cool and dry place.	EN 455-4:2010 / Disposable Medical Gloves - Requirements and Tests for Determining Shelf Life	Symbols that meet the specifications and manufacturer information of the final product have been used in accordance with the standard.
Shelf life	5 year		It should be stored at room temperature and in a moisture-free environment, but should not be exposed to direct sunlight.

PRODUCT FEATURES
* It is skin-friendly as it is made of 100% Nitrile and does not contain latex proteins. * It is more resistant to puncture than latex and vinyl gloves. * It is more chemically resistant than latex and vinyl gloves. * It is powder-free and is preferred for those whose skin is sensitive/allergic to powder. * It has superior protection against chemicals and viruses. * It can be easily worn with its curved cuff structure. * It complies with the elasticity properties specified in national norms. * It complies with the dimensions specified in national norms. * The fingertips are rough for easy adhesion to the surface. * It is suitable for both hands thanks to its physical structure. * There are 100 gloves (50 pairs) in a box. * It has a shelf life of 5 years from the date of production. * It has been proven that domestic production is made. * It is suitable for use in areas such as Hospitals, Laboratories, Food Plants, Chemical Industry, Automotive Industry, Cleaning etc. * The glove features are manufactured and tested in accordance with ASTM D6319, EN 374, EN 455 and EN 1186 standards.

1.10 ESTAŞ Glove Product Dimensions

Length, width and thickness information for ESTAŞ Gloves sizes S, M, L and XL are given in Table 1.7.

Table 1.7 Glove Product Dimensions

PRODUCT DIMENSIONS				
Feature	**Glove Size**	**For The Final Product**	**Output Standard/ Standard Name**	**Explanation**
Length (mm)	All Dimensions	≥ 240 mm	EN 455-2:2024/ Disposable medical gloves - Requirements and tests for physical properties	According to EN 455-2 Standard, glove length is determined as minimum 240 mm for each size. While palm width varies in each size, in the S/M/L/XL sizes we produce, they are minimum 80, 95, 110 and 120 mm wide respectively. The fingertip, palm and cuff thickness of the glove is minimum 0.05 mm in all sizes.
Palm Width (mm)	S (6-7)	80±10		
	M (7-8)	95±10		
	L (8-9)	110±10		
	XL (9-10)	120±10		
Thickness (mm)	All Dimensions	Fingertip: Min. 0.05 mm		
		Palm: Min. 0.05 mm		
		Cuff: Min. 0.05 mm		

ESTAŞ Gloves are produced within the scope of EN 455-2:2024 standard and the dimensions of the products produced meet the standard requirements.

1.11 ESTAŞ Glove Physical, Chemical and Performance Properties

Physical properties of ESTAŞ Glove are given in Table 1.8, chemical properties in Table 1.9 and performance properties in Table 1.10.

Table 1.8 Glove Physical Properties

PHYSICAL PROPERTIES			
Feature	**Before/After Accelerated Aging**	**Output Standard / Standard Name**	**Explanation**
Elongation at Break (%)	500 Min. / 400 Min.	EN 455-2:2024/ Disposable medical gloves - Requirements and tests for physical properties EN 455-4:2009/ Disposable medical gloves - Requirements and tests for determining shelf life ASTM D6319-19:2023/Standard Specification for Nitrile Examination Gloves for Medical Applications	Before and after the accelerated aging test, the gloves meet the specified physical requirements.
Tensile Strength (Mpa)	14 Mpa Min.		
Breaking Force (N)	≥ 6		

ESTAŞ Gloves are manufactured within the scope of EN 455-2:2024, EN 455-4:2009 and ASTM D6319-19:2023 standards, and the physical properties of the products produced meet the standard requirements.

Table 1.9 Glove Chemical Properties

CHEMICAL PROPERTIES			
Feature	**Testing Method**	**Output Standard/ Standard Name**	**Explanation**
Chemical Penetration	To determine the resistance of gloves to chemicals, a permeability test is applied to some of the 16 chemicals. As a result of this process, the type of glove is determined.	EN 16523-1:2015/ Determination of material resistance to permeation by chemicals - Permeation of liquid chemicals under conditions of continuous contact	Our glove has shown resistance to KJTP coded Sodium Hydroxide, n-Heptane, Formaldehyde and Hydrogen Peroxide chemicals for 30 minutes and has been proven to be at Level 2. It is also classified as Type B according to the 374-1 standard.
Resistance to Degradation	The resistance of a protective glove material to degradation by a liquid chemical is determined by measuring the change in puncture resistance of the glove material after continuous contact of the outer surface with the test chemical.	EN 374-4:2019/ Protective gloves against hazardous chemicals and microorganisms – Determination of resistance to degradation by chemicals	The resistance of the gloves to degradation was calculated by tests carried out by an approved body.

ESTAŞ Gloves are manufactured within the scope of EN 16523-1:2015, EN 374-4:2019 standards and the physical properties of the products produced meet the standard requirements.

- ✓ Within the scope of TS EN 16523-1 standard,
  - • 37% Formaldehyde,
  - • n-Heptane,
  - • 40% NaOH,
  - • 30% Hydrogen peroxide

permeability tests were applied to the gloves against 4 chemicals. It passed the tests successfully and has permeability against 4 chemicals.

- ✓ Gloves within the scope of TS EN 16523-1 / ASTM D6978-05 (2019) / ISO 6529 standard,
  - 1 ppm Doxorubicin
  - 1 ppm Cyclophosphamide
  - 1 ppm Daunorubicin
  - 20 mg/ml Etoposide
  - 10 mg/ml Dacarbazine
  - 25 mg/ml Methotrexate
  - 50 mg/ml Fluorouracil
  - 6 mg/ml Paclitaxel
  - 10 mg/ml Thiotepa
  - 3.3 mg/ml Carmustine
  - 20 mg/ml Cyclophosphamide
  - 2 mg/ml Doxorubicin Hydrochloride

Permeability test was applied to 12 chemotherapy drugs. It passed the tests successfully and is permeable to 12 drugs. It is also used as chemotherapy gloves.

Table 1.10 Glove Performance Characteristics

PERFORMANCE CHARACTERISTICS			
Feature	**Testing Method**	**Output Standard/ Standard Name**	**Explanation**
Sealing (sealing water leakage testing)	Gloves are subjected to air leakage and water leakage tests.	EN 374-2:2019/ Protective gloves against hazardous chemicals and microorganisms – Determination of resistance to penetration	The gloves have passed the air leakage and water leakage test.
AQL (Acceptable Quality Level)	≤1,5	EN 455-1:2020/ Disposable medical gloves - Requirements and tests for hole-freeness	The Acceptable Quality level (AQL) for nitrile examination gloves is ≤1.5.

ESTAŞ Gloves are produced within the scope of the 455-1:2022 standard and the products produced are tested according to the AQL (Acceptable Quality Level) ≤1.5 limit.

1.13 ESTAŞ Glove Factory R&D Studies

1.13.1 Optimization Study in Glove Production

Our company is the only company in Turkey that produces nitrile gloves. Our gloves have a higher quality structure compared to the market and we have planned recipe development studies to increase this quality and produce better gloves than the rival companies in the market. The lack of a glove market in Turkey and our desire to reduce our dependency on foreign countries by producing gloves locally in Turkey at a level that can compete with the few companies that produce gloves worldwide and to make our company's name known to the world, as well as the lack of sufficient information in the literature about the formula and the effects of the chemicals used in the formula, have led to the initiation of the project.

Since we have to produce our product within the scope of the relevant standards, it is important and challenging for us to be able to provide the values in the standard. Within the scope of the project, optimization experiments were carried out in the mini production line where our company has an infrastructure and where we carry out R&D studies to produce high mechanical strength, chemically impermeable and flawless gloves. Within the scope of the study, one of the chemicals used in the recipe was kept constant and the physical and chemical effects of the changing amounts of the other chemicals on the product and production were examined. This stage was carried out separately for each chemical and glove samples were produced (Figure 1.6). According to the determined optimum amounts, the optimization table given in Table 1.11 was created. After determining the ideal usage rates of the gloves produced according to Table 1.11, physical tests were carried out and the physical and chemical properties table of the glove (Table 1.12) was created according to the ideal usage rate.

In this study, it is aimed to observe the effects of increasing and decreasing amounts of chemicals on the durability, strength, chemical permeability, impermeability and physical test properties of the glove by determining the process of transition to domestic and national nitrile glove production line investment and production activities and the prescription determination studies for nitrile glove production. Due to the lack of sufficient

information in the literature, this study aims to determine the optimum conditions and produce higher quality, durable and flawless gloves and to be better than the world's leading glove brands compared to other competitors in the market.

Figure 1.6 Glove Samples Produced in Mini Production Line

Table 1.11 Optimization Table

Chemical Name	Change in usage rates	Usage range (%)	Breaking force (min. 6 N)	Elongation at Break (min. 500%)	Tensile Strength (min. 14 MPa)	Sealing (sealing water leakage testing)	Weight/ Thickness	pH
NBR(Nitrile)	+	16				↑	↑	
	-	13				↓	↓	
$Ca(NO_3)_2$	+	30				↑	↑	
	-	20				↓	↓	
ZnO	+	1,3	↑	↓	↑			
	-	0,3	↓	↑	↓			
KOH	+	0,7	↓	↓	↓			↑
	-	0,3	↑	↑	↑			↓
S	+	0,6	↑	↓	↑			
	-	0,2	↓	↑	↓			

The usage rates determined as a result of the optimization study and the physical test results measured depending on these rates are shown in the table.

Table 1.12 Physical and Chemical Properties of Gloves According to Ideal Usage Rate

CHEMİCAL NAME	USAGE RANGE (%)	IDEAL USAGE RATE DETERMINED AS A RESULT OF THE OPTIMIZATION STUDY (%)	PHYSICAL AND CHEMICAL PROPERTIES OF GLOVES ACCORDING TO IDEAL USAGE RATE				
			Breaking Force (min. 6 N)	Elongation (min. %500)	Tensile Strength	Thickness (mm)	Weight (mm)
NBR	13-16	15	7,5	540	23	0,11	6
Ca(NO3)2	20-30	21,6					
ZnO	0,3-1,3	0,9					
KOH	0,3-0,7	0,45					
S	0,2-0,6	0,21					

1.13.2 Anesthesia Balloon Prescription Study and Production

Within the scope of the project, it is aimed to develop the prescription used in the production of existing nitrile gloves and the process parameters in the production line depending on this process in order to produce anesthesia balloons with the desired physical properties.

Our desire to reduce the dependency on foreign countries by producing anesthesia balloons locally in Turkey and to make our company's name known to the world caused the project to be initiated.

Within the scope of the project, trial studies were carried out in the mini production line developed by our company. Optimum process parameters were determined and anesthesia balloons were produced with the existing nitrile glove prescription (Figure 1.7). According to the physical test results, more durable, higher quality and thicker balloons were tried to be produced by changing the proportions of chemicals. Balloons with the desired properties were produced but could not be taken to the mass production line. It was decided to suspend the project and continue the project in more advanced processes.

Figure 1.7 Anesthesia Balloon Sample Production

1.13.3 Glove Production with Antibacterial Paint

In Sivas, where our current factory is located, a dye was purchased from a company that developed and produced a dye with proven antibacterial properties, and this dye was used instead of the dye we use in glove production in our company or together with this dye, aiming to both reduce costs and make an environmentally friendly production within the scope of the project. If the studies are successful, our glove will have antibacterial properties and will also gain functional properties.

The concentration and dyeing intensity of the purchased antibacterial dye were compared with the dye we currently have and whether it mixed with other chemicals was examined.

Each chemical was treated separately to see if it interacted and if so, what kind of interaction it was, and to determine the chemical and dye ratios. However, since the chemical/dye interaction could not be achieved and precipitation occurred between the dye and chemical, a homogeneous mixture could not be formed and the optimum amount could not be determined and the production recipe could not be prepared. Therefore, since the trial could not be done on the mini production line, no glove sample was produced.

1.13.4 Chemotherapy Glove Prescription Study and Production

Chemotherapy resistant gloves should be used when preparing chemotherapy drugs or when in contact with the drug. Since studies have shown that powder increases permeability, powder-free latex gloves should be

used in applications. Our company wanted to test the resistance of the nitrile glove we currently produce against chemotherapy drugs. This request led to the initiation of the project. Chemotherapy gloves are used by many state hospitals, private hospitals and clinics. The project aimed to expand our product portfolio and add technical permeability to chemotherapy drugs to the nitrile glove we currently produce, thus increasing the sales rate, making our company's name known with domestic production and increasing the number of chemotherapy gloves, which have few equivalents in the market, so that they can be more easily accessed when needed.

In the project, nitrile powder-free thick gloves were produced within our company to be suitable for chemotherapy gloves. Thick gloves were produced by increasing and decreasing the amount of existing chemicals in a way that would reduce permeability and increase thickness. Physical tests were applied to the produced gloves in our own laboratory and they were sent to accredited laboratories for resistance testing against chemotherapy drugs.

Our company attaches importance to local production with the slogan of local and national production. Since there is no other company producing nitrile gloves locally in our country, chemotherapy gloves are not produced in our country but imported from abroad and since these gloves are less available in the market than normal nitrile gloves with their chemotherapy glove feature, their price is also high, which is the reason for the project to be started.

Our glove has been subjected to permeation tests against 12 chemotherapy drugs in accredited laboratories and has passed the test for all 12 chemicals. Therefore, our glove is also offered to the market as a chemotherapy glove.

1.13.5 Sterile Surgical Glove Prescription Study and Production

Hygiene is very important in almost all professions. After the Covid-19 outbreak, the importance of protective equipment used in the healthcare field has also increased. One of the important equipment is protective gloves. This issue is of utmost importance, especially in surgical operations where sterility should be given more importance. Sterile gloves should be used in surgical areas in addition to normal examination gloves. In this way, patients are prevented from contracting diseases due to external effects. Sterile gloves are a type of glove that has been purified from microorganisms with special

processes. The same care is taken in packaging. Sterile gloves are a type of glove that has been purified from microorganisms with special processes. Sterile gloves are an important part of infection prevention. They help prevent patients and healthcare providers from coming into contact with potentially harmful bacteria and viruses. They also help reduce the risk of cross-contamination between patients and staff.

The need for sterile surgical gloves in health institutions in Turkey and the demands resulting from these needs, as well as the limited domestic product and import of imported products into Turkey, have led to the initiation of the project. With this project, sterile surgical glove studies have been tested in our mini production line, which has an infrastructure in our company. It is planned to provide surgical glove standards and take them to the mass production line after the minimum values in the standard are provided, and the mass-produced gloves will be sterilized and packaged in the clean room, which also has an infrastructure in our company. With this project, it is aimed to eliminate infection risks in surgical applications in the health sector and to contribute to the country's economy by increasing support for domestic production together with production.

Our company wanted to produce sterile surgical gloves with the help of the existing nitrile glove prescription. The only difference between the sterile surgical glove and the non-sterile nitrile examination glove we currently produce is the mold difference. With this project, sterile surgical glove studies were tested in our mini production line, which has an infrastructure in our company. Within the scope of the supplied surgical glove standards, it was planned to be taken to the mass production line after the minimum values in the standard were provided, and then sterilized and packaged in the clean room with the infrastructure established in our company. The only difference between the sterile surgical glove and the non-sterile nitrile examination glove we currently produce is the mold difference.

The gloves met the required criteria on the mini production line, sample gloves were produced, but it was decided to suspend the project and continue the project in more advanced stages.

1.13.6 Sterile Examination Glove Prescription Study and Production

Surgical gloves are disposable gloves used to help prevent cross-contamination between staff and patients during medical examinations and procedures. Although glove use is used to prevent the spread of microorganisms, it is not as important as hand washing. Because the main purpose of glove use is to prevent microorganisms that are transmitted to the staff's hands from the environment or the patient from being transmitted to another patient. Healthcare personnel must wear sterile gloves when touching the patient's mucosa, skin areas with compromised skin integrity (cuts, scratches, wounds, burns, etc.), moist/wet body areas, and any type of instrument application to the patient.

Sterile gloves are gloves that are purified from microorganisms in a clean room. This project aims to eliminate infection risks in surgical applications in the health sector and to contribute to the country's economy by increasing support for domestic production together with production. In Turkey, the high number of people applying to hospitals and the high number of hospitals show that there is a high need and demand for sterile examination gloves in health institutions. This need and the desire to produce domestic products instead of imported products led to the initiation of the project. Our company wanted to produce sterile examination gloves with the help of the existing nitrile glove prescription.

With this project, sterile examination glove studies were tried in our mini production line, which has infrastructure in our company. Within the scope of the current examination glove standards, it was planned to be taken to the mass production line after the minimum values in the standard were provided, then sterilized and packaged in the clean room with the infrastructure established in our company. The only difference between the sterile examination glove and the non-sterile nitrile examination glove we currently produce is that the gloves are sterilized.

The gloves met the necessary criteria in the mini production line, but it was decided to suspend the project and continue the project in more advanced processes.

1.13.7 Vinyl Glove Recipe Study and Production

When comparing the pre- and post-Covid-19 periods, there have been differences in terms of consumer demands in terms of products and product groups all over the world, and the demand for medical products such as gloves with a long shelf life has increased. Disposable gloves took the first place in the fastest growing categories. Investors have turned to this area as the demand for gloves in Turkey increased during the pandemic. In addition to our main product, nitrile gloves, our company wanted to expand its product portfolio and work to produce vinyl gloves due to the high demand for vinyl gloves. Vinyl gloves are one of the glove types that provide high protection after nitrile gloves. Those who are allergic to latex generally prefer nitrile or vinyl gloves. In addition, vinyl gloves have a barrier feature in low-risk and short-term operations.

The project aims to develop the formulations in the literature as an R&D study, to create our own recipe, to develop process parameters, to contribute to domestic production by starting mass production by our company.

The project was initiated to develop our product portfolio, to support domestic production and to announce our company's name in our country, and to offer an alternative type of personal protective equipment with the vinyl glove produced. The formulations available in the literature were used to produce vinyl gloves with the desired physical properties. The raw materials used in these formulations were supplied and their chemical mixtures were prepared. Trials were conducted with ceramic glove molds using the prepared recipes in the mini production line available within our company. The trials yielded successful results and glove samples with the desired properties, quality and durability were produced as shown in Figure 1.8, but it was decided to suspend the project and continue the project in later processes.

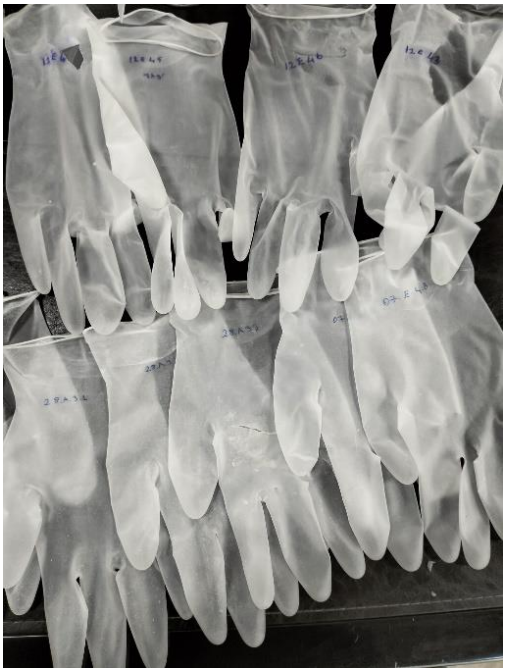

Figure 1.8 Vinyl Glove Sample Production

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CHAPTER 5

ESTECH APPROACH: INNOVATING INDUSTRIAL AUTOMATION

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INTRODUCTION

ESTECH is an engineering company that develops innovative solutions to increase efficiency, reduce costs and ensure quality in industrial production processes. Its commitment to technology enables companies to strengthen their competitive advantage and offers effective solutions to the challenges encountered in production processes. ESTECH aims for excellence in production processes by combining the latest developments in engineering and innovative designs with sectoral needs. Each system develops not only speeds up production lines, but also ensures more reliable and error-free processing of processes.

In parallel with the developing technology, our company focuses on developing automated systems to increase efficiency in design and production processes. The solutions offered by ESTECH minimize labor and time losses by increasing production speed, especially in industrial production areas that require precision. In addition, it improves quality control and prevents defective products from entering production. ESTECH not only increases productivity, but also reduces operational costs, which enables companies to have a more sustainable production structure.

The developed systems are carefully tested at every step from the design stage to the production stage and their compliance with quality standards is guaranteed. In this way, companies can manage their production processes more reliably and prevent faulty products from entering the production line. The solutions offered by ESTECH make a big difference, especially in areas such as the automotive and motor vehicle industry, which are sensitive and have high quality requirements. Systems used in different areas such as camshafts, dental devices, metal printers are designed to always operate with the highest efficiency and accuracy.

In the production of camshafts, automatic measurement and control systems, which replace traditional manual measurement methods, provide significant improvements in production lines. These systems quickly detect defects in camshafts and prevent them from entering the production process. Sensors, magnetic pistons and servo motors are used to measure with high precision, preventing faulty products from entering the production line. The quality of production is increased by precisely controlling each stage of the camshafts with the systems provided by ESTECH.

In addition, ESTECH offers systems that maximize precision in assembly processes such as ring, ring and bearing assembly. Error-controlled assembly machines developed for such assemblies detect errors at every assembly stage and increase quality by speeding up the production process. Using sensors and magnetic pistons, it is guaranteed that each assembly is carried out correctly. ESTECH ensures quality at every stage of the assembly process, while reducing labor costs on the production line.

Automatic positioning devices from ESTECH increase production speed and accuracy by accurately determining the position of the bearing oil holes of camshafts. These devices detect correct and incorrect positions with inductive sensors and LED lights. These systems operate with high accuracy, minimizing errors in production. Such systems provide a great advantage, especially in production lines with complex assembly processes.

Cam profile measurement systems are another important innovation provided by ESTECH and detect design errors and non-conformities by measuring the cam profiles on the camshafts in detail. These systems minimize losses in production and ensure the production of quality and accurate products. Automatic systems

used in cam profile measurement increase productivity by eliminating manual operations and can be used outside the laboratory thanks to their portable structure.

ESTECH also provides significant convenience in production processes with laser marking systems.

This system automates the writing and verification processes, eliminating manual positioning and control processes. It prevents problems such as incorrect writing, scratching and knocking, thus ensuring product quality. The laser marking system ensures speed and accuracy in production, while at the same time increasing productivity.

Our company not only improves production processes, but also invests in new generation production technologies. Metal printers and 3D printing technologies enable rapid prototyping in production processes and the production of complex metal parts at lower costs. DLP printers and FDM printers offer fast production processes while producing high resolution parts. Products such as dental CNC machines and alginate mixers provide more precise, fast and customized solutions in the field of dentistry.

The systems provided by ESTECH increase quality and efficiency in production lines, while at the same time reducing operational costs and saving labor (Merkle et al., 2019). Each solution equipped with technological innovations enables companies to have more efficient and sustainable production processes. ESTECH continues to add value to the sector with its engineering expertise and innovative perspective.

Automatic Control and Measurement Bench for Serial and Precise Measurement Control of Camshafts

Camshafts are critical elements that control valve timing in engines, and their correct functioning is vital to engine performance and efficiency. Therefore, the measurement and inspection processes that camshafts undergo after production are of great importance to ensure the reliability and durability of engines. Traditional measurement methods are mostly performed using manual equipment and are often prone to human error. Furthermore, these processes are time-consuming and increase production costs. Therefore, it is necessary to develop more integrated and automated solutions.

The developed automatic control and measurement machine increases productivity by combining the measurement and control processes in the production processes of camshafts in a single system. This system performs all operations from cleaning to marking of camshafts automatically (Öztürk et al., 2020). Measurement and control processes are carried out with high precision thanks to sensors, magnetic pistons, pneumatic equipment and servo motors. Cleaning the camshafts is a critical step to ensure the accuracy of subsequent measuring operations. The cleaning process removes particles from the surface of the camshafts, allowing precise measurements to be made. After cleaning, the intake and exhaust type shafts are automatically separated by special sensors. This minimizes the risk of errors during measurement.

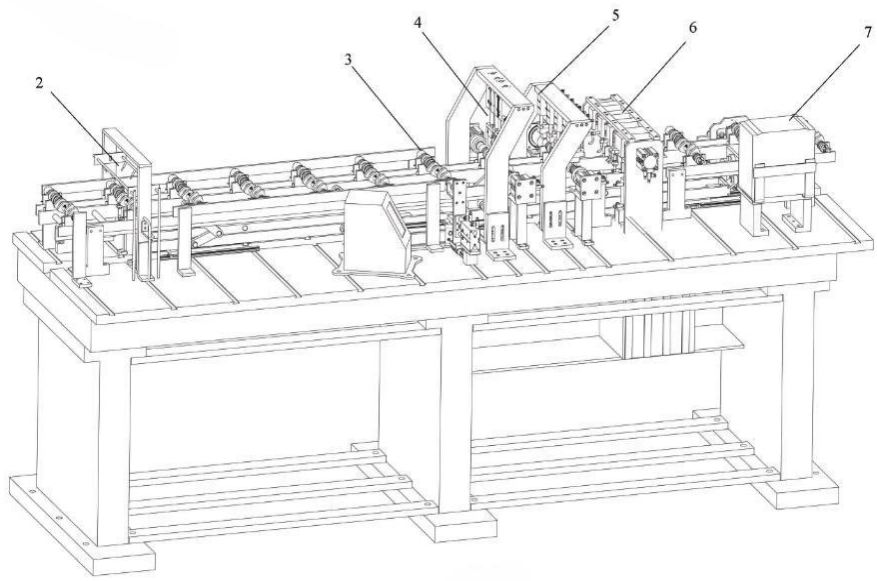

Figure 1: Automatic Control and Measurement Bench for Serial and Precise Measurement Control of Camshafts

Accuracy at the measuring points of camshafts is ensured by pneumatic gauge and probe systems. These systems carefully check the parameters at each measuring point and the system gives a warning when an incorrect measurement is detected. Thus, defective products are prevented from being passed on to subsequent processes. In addition, the marking process is also carried out automatically, thus speeding up the production process and avoiding wasted time (Zhang et al., 2015). This innovative machine eliminates the errors encountered with manual operations and increases the competitiveness of companies by reducing production costs. These improvements in speed, precision and productivity visibly improve engine performance.

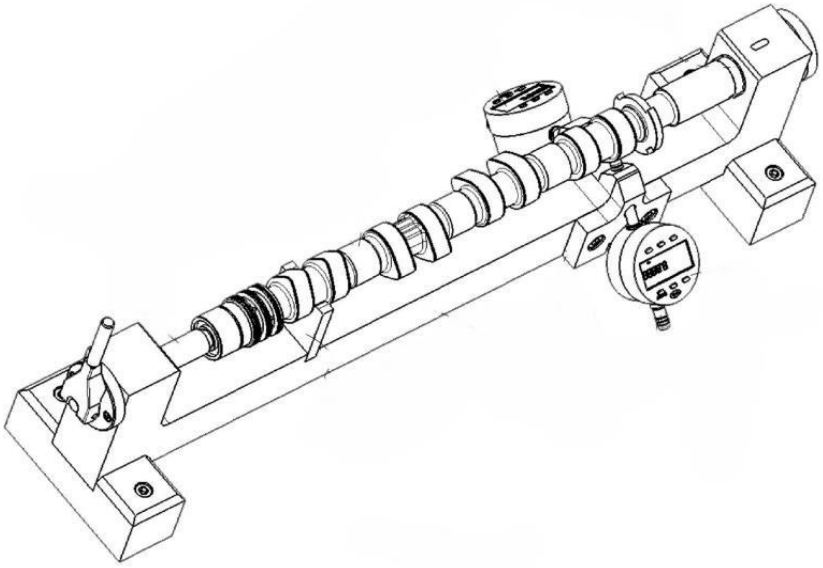

Figure 2: Control and Measurement Bench

Crescent Jig

Another important system developed to perform measurement and control operations with high precision in the production processes of camshafts is the crescent gauge. This system is used to measure the distance between the flanges of the camshafts and offers a fast and error-free measurement process by minimizing the need for manual intervention. The crescent gauge consists of a travelling part, gauging arms, springs and sensors. The travelling part is a metal structure with different geometrical properties and makes accurate measurements by detecting tolerance differences between flanges. The gauge arms initiate the measuring process by contacting the expanding conical part of the movement part.

The springs ensure that the gauge arms remain in a fixed closed position, allowing freedom of movement during the measurement. In addition, the elastic structure of the springs increases the sensitivity of the system. Inductive sensors in the system detect the position of the moving part and transfer the data to the control unit. This data determines whether the distance between the flanges is within tolerance limits. If an out-of-tolerance situation is detected, the system warns the user and prevents the faulty parts from proceeding to the next stages. In addition, the cleanliness of the measurement

environment is ensured, increasing measurement accuracy and ensuring reliable results.

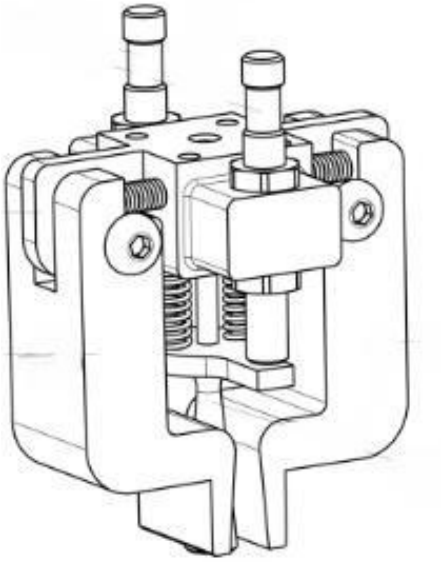

Figure 3: Crescent Jig

Automatic Positioning Device and Working Principle

Accurately determining the angular positions of the bearing oil holes on the camshafts is a critical step for engine efficiency and durability. Accurate positioning of these holes can be done with automatic positioning devices to eliminate errors caused by manual methods. The automatic positioning device consists of components such as pins, gauges, positioning parts, inductive sensors and LED lights. These components increase the precision of the device and ensure high accuracy during the positioning process.

The positioning process starts with the determination of the reference point and the positioning of the gauge according to this reference. Then, the positioning pin is aligned with the specified holes and its accuracy is verified with inductive sensors. LED lights provide feedback to the user by showing the correct position with a green light and the incorrect position with a red light. The system can operate in accordance

with both semi-automatic and fully automatic systems. In semi-automatic system, the operator adjusts the position manually, while in fully automatic system, the whole process is carried out by a motorized mechanism.

This automatic positioning device can be used not only for camshafts but also for other systems that require angular positioning. The visual feedback mechanism and precise measurement capability minimize errors in the production process and improve quality. This innovative device ensures speed, accuracy and efficiency in the production process, while eliminating the difficulties encountered with manual methods.

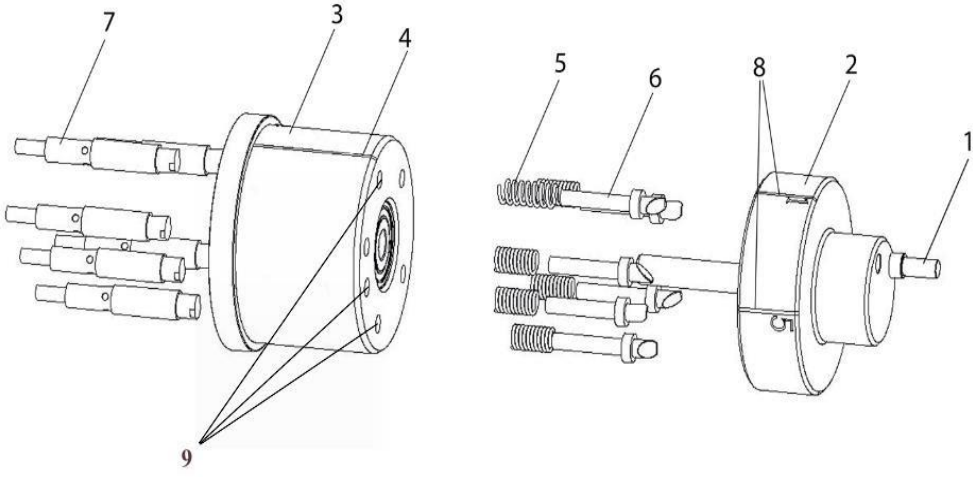

Figure 4: Automatic Positioning Device and Working Principle

Error Controlled Assembly Machine for Camshafts with Ring-Ring-Bearing

The assembly of camshafts is critical to the operation of engines. The correct assembly of camshafts has a direct impact on the efficiency, durability and longevity of engines. The present invention describes an assembly machine that performs the ring, collar and bearing assembly of camshafts with extremely high accuracy and reliability. The machine continuously monitors each stage of the assembly process with sensors and control mechanisms, thus minimizing the margin for error in each operation and guaranteeing assembly quality. The system automates the processes that take place at each assembly

stage, preventing wasted time and increasing labor productivity.

The design of the assembly machine utilizes a variety of technologies to ensure that each process step is completed safely and quickly. The camshafts are transported by trolleys on the assembly line to each process point. Sensors are activated at each operation and the accuracy of the assembly is checked instantly. In this way, when any error is detected, the system automatically intervenes and corrects the process. The closed cabin design of the bench allows measurements to be made more accurately, and measurements are carried out in an environment free from external factors. This design minimizes measurement errors and optimizes quality control.

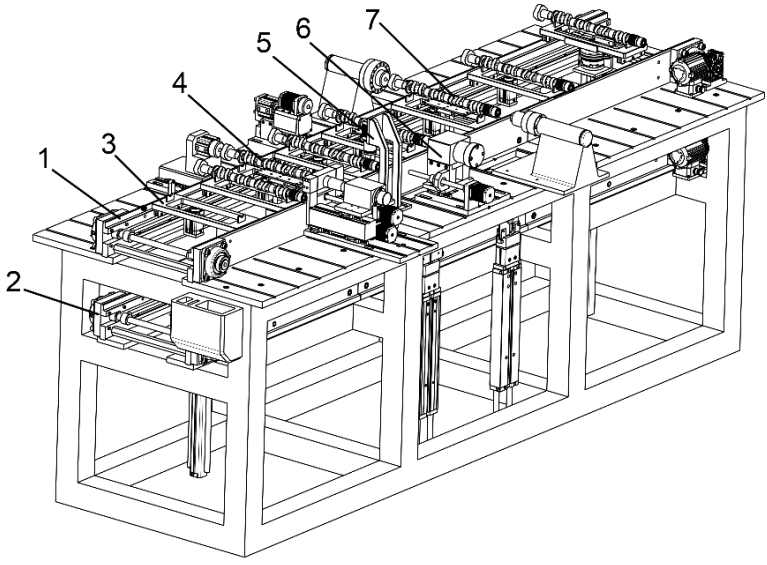

Figure 5: Error Controlled Assembly Machine for Camshafts with Ring-Ring-Bearing

The advantages of this machine are speeding up the production process, reducing the margin of error and requiring less labor. Thanks to sensors and control mechanisms, errors made during assembly can be detected and corrected at an early stage. This results in fewer defective products and a high-quality production process. As the camshafts are assembled accurately at each stage, potential errors that may occur during the process are prevented, thus ensuring the quality of the final product. This system creates a faster, more efficient and safer production environment compared to traditional

methods.

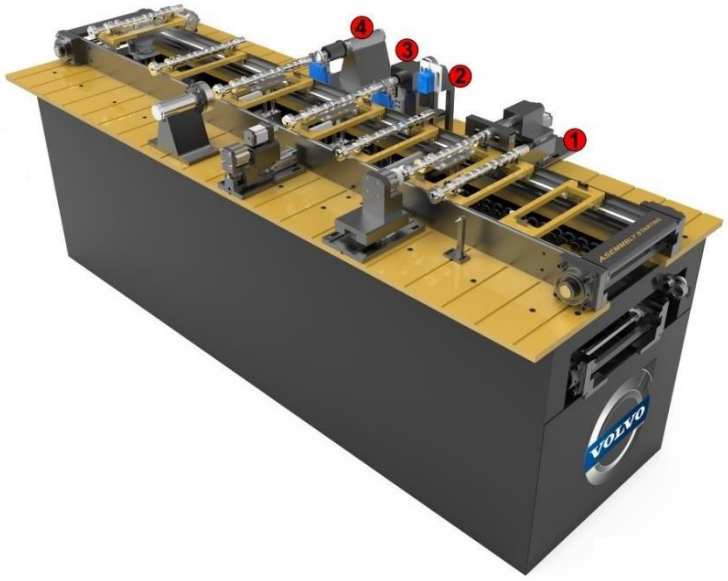

Figure 6: Error Controlled Assembly Machine for Camshafts with Ring-Ring-Bearing

Laser Marking

The process of writing on camshafts is very important for the identification and traceability of engine parts. In conventional methods, this is usually done manually, which is both time-consuming and error-prone. The present invention fully automates the writing and verification of the laser marking machine on camshafts, significantly speeding up the production process. The camshafts are guided to the laser marking process by trolleys and brought into the writing position. After this stage, the verification process is carried out. In the new system, the writing verification process is performed with a writing reader and a visual warning is sent to the operator for correct writings.

In traditional marking methods, positioning is usually done manually and the writing is checked by eye. This can create risks in terms of legibility, accuracy and clarity of the writing. However, the new laser marking system

eliminates errors during the writing process by accurately positioning the camshafts. In addition, the accuracy of the writing is automatically checked without the need for manual writing control. This system prevents damage to the camshafts during writing and prevents undesirable results such as scratches or knocking. Type verification is performed by means of a type reader, resulting in a faster and more accurate marking process.

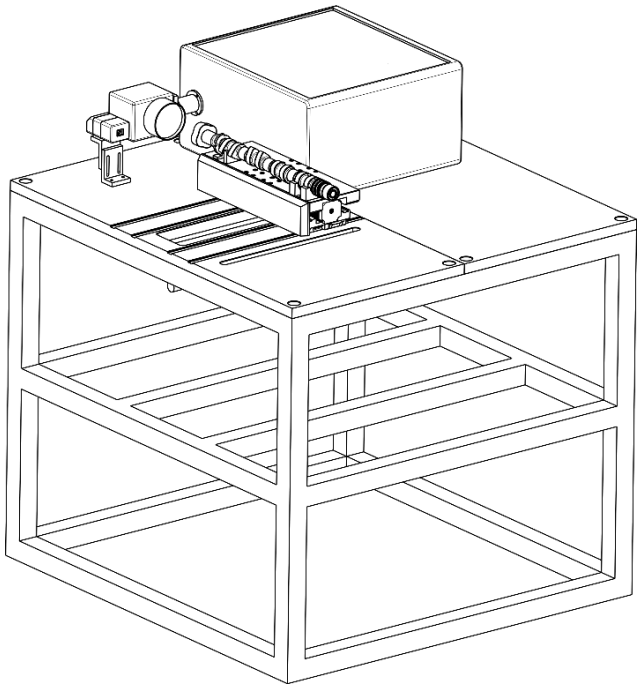

Figure 7: Laser Marking Device

Laser marking not only ensures fast and accurate marking, but also minimizes errors in the production process. This system significantly reduces the error rate in production, improves quality and ensures defect-free products reach the customer. Furthermore, thanks to the automatic verification process, high accuracy is achieved even where manual control is weak. By optimizing the writing and verification processes of camshafts, this invention significantly improves the quality of the production process.

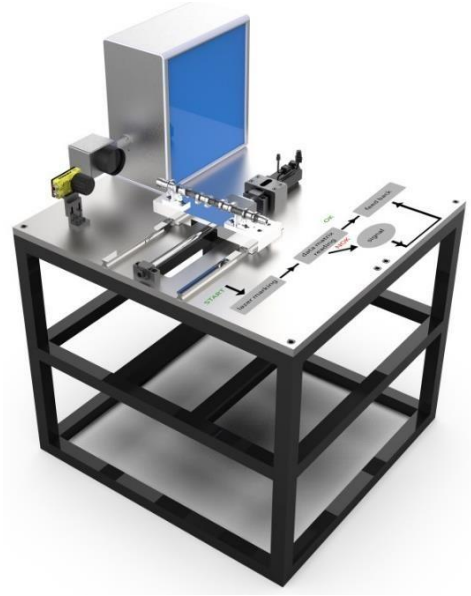

Figure 8: Laser Marking Device

Pin Length and Diameter Measuring Machine

The present invention provides an advanced system capable of performing length and diameter measurements of pins in an automated manner. The design ensures that the pins are transported in the correct sequence and that any faulty product is quickly detected and diverted during the measurement process. This ensures high accuracy in the measurement process and makes the production process more efficient. This automated system takes accurate measurements of the pins without the need for human intervention and performs these measurements without any errors.

The pins are taken into the measurement process in the correct sequence thanks to the design-specific transport systems. If any errors are detected during the measuring process, the faulty product is directly routed to the faulty product bin. This prevents the passage of defective products on the production line and makes production safer. The detection and routing of defective products increases the efficiency of the production process and maximizes quality. Furthermore, the automatic operation of the system saves labor, eliminates human error and reduces maintenance costs.

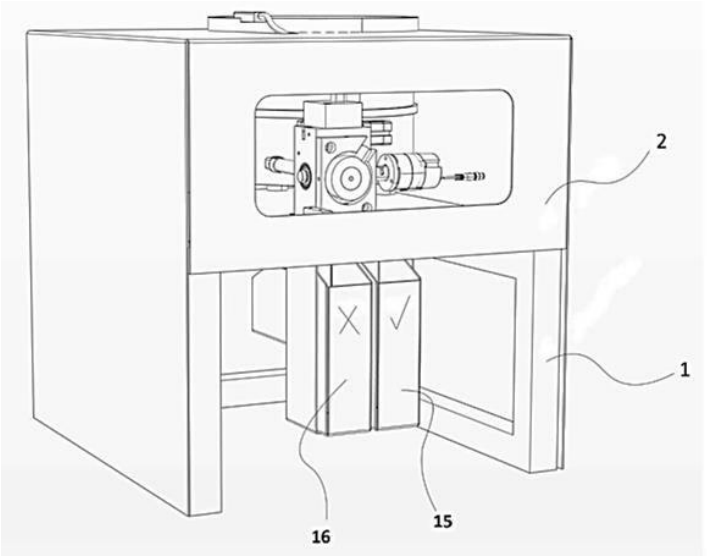

Figure 9: Pin Length and Diameter Measuring Machine

The compact structure of the system does not take up much space in the production area and allows the production process to continue without interruption. This allows the production line to operate in a more organized and efficient manner. Measurements made without the need for operator intervention reduce error rates in production and allow the production of high-quality products. This system ensures speed, accuracy and efficiency in production processes, guaranteeing high quality at every stage.

As a result, these new designs optimize production processes, increase productivity and continuously improve product quality. Both the assembly machine, laser marking and pin measuring systems replace traditional methods, providing an error-free, fast and efficient working environment in the production process. These inventions are important steps in shaping the future of industrial production processes.

Figure 10: Pin Length and Diameter Measuring Machine

Cam Profile Measuring Machine

Automatic Cam Profile Measurement and Verification System is a technology that enables precise measurement of cam profiles on camshafts and aims to improve production quality. This system has been developed to improve the quality control processes of camshafts, especially in industries that require precision such as automotive and motor vehicles. The machine places the camshaft on the V-bearing and fixes it with a pneumatic cylinder. Then, while the camshaft is rotated 360° with a stepper motor, the probe devices contact the cam profile and perform measurements with high precision.

The data obtained during the measurement is transferred to the Programmable Logic Controller (PLC) system. Detailed geometrical analyses are performed by means of software. The system increases the accuracy at each measurement point, enabling faulty products to be detected before production. In this way, manual operations are eliminated and the error rate is minimized. In addition, the system's portability offers the flexibility to be used in environments outside the laboratory, so that quality control processes can be implemented anywhere.

The Kam profile measurement system offers much faster and more accurate measurements, especially compared to traditional methods. User-friendly software analyses the measurement data and presents the results in graphical reports. In this way, the production processes of enterprises become more efficient, while significant improvements are achieved in quality control processes.

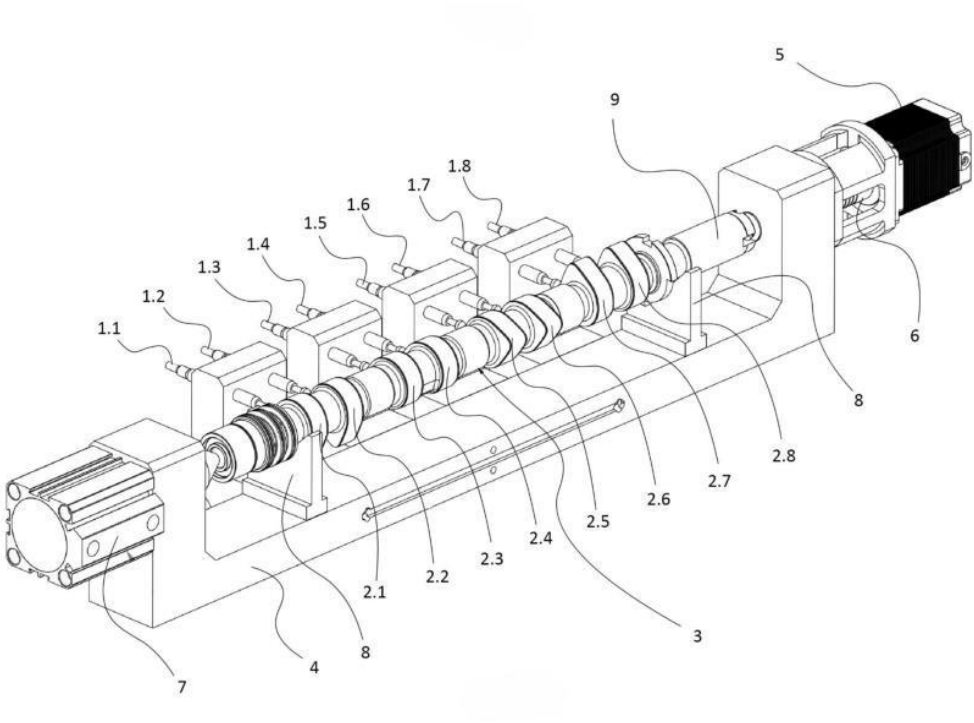

Figure 11: Cam Profile Measuring Machine

Automatic Measuring Device Providing Ring Control for Camshafts with Ring-Ring-Bearing on it

Designed to improve the quality production processes of motor vehicles, this device automatically checks the condition of rings, rings and bearings in camshafts. In traditional applications, ring inspection is usually done manually, which can lead to time losses and false detections. However,

this automatic system checks the rings quickly, enabling faulty products to be detected before production resumes.

The device is equipped with components such as pneumatic cylinders and manometers and checks the condition of each ring by pressure measurements. The checking process takes only 10 seconds and the results are communicated to the user via the HMI display with visual and audible alerts. This fast and precise inspection saves significant time and costs in production processes, improves quality and ensures customer satisfaction. Defective segments are detected at an early stage, minimizing the amount of defective products leaving production.

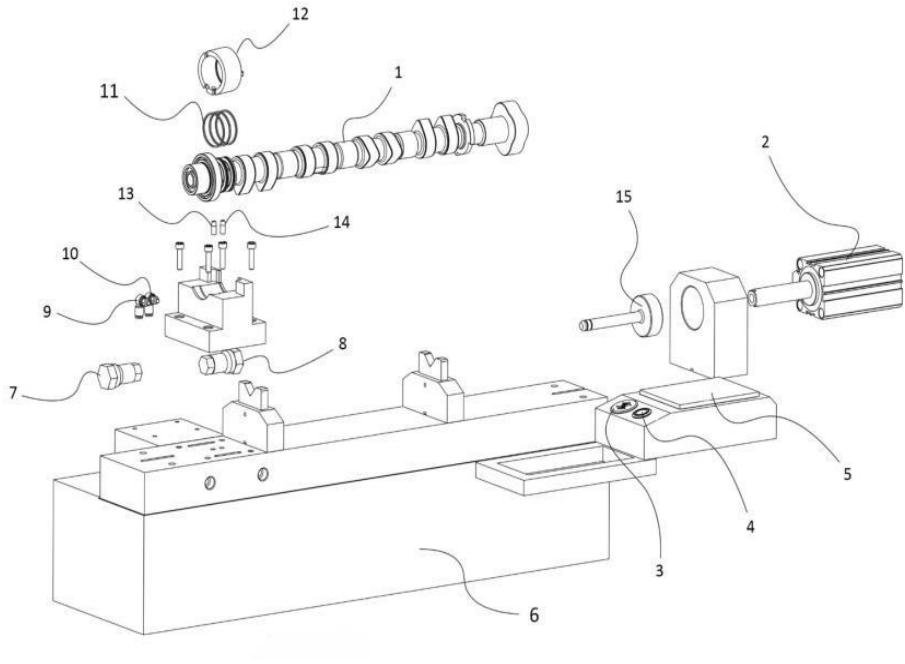

Figure 12: Automatic Measuring Device Providing Ring Control for Camshafts with Ring-Ring-Bearing on it

9-Axis Length Completion, Hole Drilling and Hole Reaming Transfer Machine

This invention includes a transfer machine where length completion, hole drilling and hole reaming operations are performed simultaneously on unmachined shafts. This system speeds up the machining process and

increases efficiency, eliminating time losses caused by performing each operation on a separate machine. In traditional machining methods, separate machines are used for each operation and time is lost with each pass.

This transfer machine consists of components such as chassis, shaft centering mechanism, servo motors and transfer mechanism. Length completion, hole drilling and hole reaming units operate quickly and efficiently, allowing all operations to be performed simultaneously. Thus, production time is shortened, costs are reduced and overall efficiency is increased. This machine shortens machining times, reduces maintenance costs and optimizes the overall efficiency of the production line.

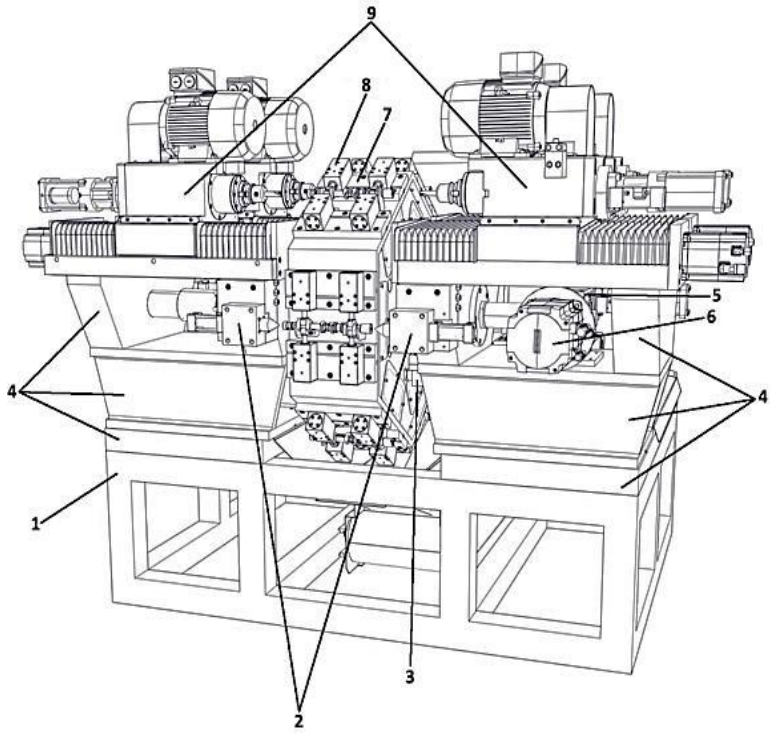

Figure 13: 9-Axis Length Completion, Hole Drilling and Hole Reaming Transfer Machine

Metal Printer

Metal printers were developed for the rapid and precise production of metal parts used in industrial applications. Unlike traditional metal processing methods, these printers offer design flexibility and customizability by producing directly with digital files. Metal printers combine metal materials in layers using laser melting or powder bed melting and create the desired part. The biggest advantage of this technology is that parts that are difficult to produce with traditional processing methods, such as complex geometries and internal structures, can be produced (Ji, Mirkoohi, Ning, Liang 2020). Metal printers are used in prototyping, small-scale production and spare part production in sectors such as automotive, aviation, medical and defense industries. In addition, they offer low-cost and rapid prototyping, speeding up R&D processes and reducing design errors (Hilpert et al., 2018).

Figure 14: Metal Printer

Figure 15: Metal Printer samples

DLP Printer (Digital Light Processing)

DLP printers use layered manufacturing technology to light-cure liquid resin and build one layer at a time. These printers are especially advantageous in applications that require high resolution and speed. DLP printers are faster than other types of 3D printers because they light-cure each layer at the same time. These

printers produce parts that can print fine details with high precision and speed using liquid resin. It is widely used in prototyping, production and production of precision parts, especially in dentistry, jewelry, automotive and medical fields. DLP printers offer an important technology for sectors that require quality and speed, and also provide low-cost production.

Figure 16: DLP Printer (Digital Light Processing)

FDM Printer (Fused Deposition Modeling)

FDM printers are a common type of 3D printer for industrial and hobby use. These printers, where plastic materials (usually thermoplastics such as ABS and PLA) are used as filaments, work on the principle of depositing melted filament layer by layer. FDM printers offer rapid prototyping and low-cost production, and durable plastic parts can be produced. The advantages of these printers include ease of use, a wide range of materials and cost-effectiveness. FDM printers have a wide range of uses in the automotive, aviation, education, industrial design and medical fields. However, more expensive printers may be preferred for applications requiring high precision, but they offer efficient and low-cost solutions in general production processes.

Figure 17: FDM Printer

Dental CNC (Dentistry CNC Machine)

Dental CNC machines are high-precision processing machines that produce dentures, crowns, bridges, dental implants and other dental devices used in dentistry. CNC (Computer Numerical Control) technology allows parts to be cut, shaped and processed with digital data. These machines offer more customized and faster production processes in dentistry. Dental CNC machines work integrated with computer-aided design (CAD) and computer-aided manufacturing (CAM) software, allowing the rapid production of dental prostheses suitable for the individual needs of patients. Thus, production time is shortened, accuracy is increased and patient satisfaction is ensured (Özcan et al., 1986). These machines, which increase efficiency in dentistry, are of great importance especially in aesthetic and functional dental treatments.

Figure 18: Automatic Control and Measurement Bench for Serial and Precise Measurement Control of Camshafts

Alginate Mixer

The alginate mixer automates and speeds up the process of mixing alginate in dentistry. Alginate is a widely used material for taking dental impressions, and getting the right mix is critical to creating high-quality and accurate dental impressions. This mixer produces high-quality dental impressions with maximum efficiency and speed by mixing alginate and water homogeneously. Using an alginate mixer reduces human errors, saves time, and ensures that the material reaches the right consistency (Alçelik et al., 2020). In this way, dentists can obtain faster, more efficient, and more accurate impressions, and achieve better results in their treatment processes.

The alginate mixer increases productivity in dental practices while also reducing material waste.

Figure 19: Alginate Mixer

Figure 20: Alginate Mixer Assembly image

CONCLUSION

As a result, the automatic control and measurement benches developed provide a significant transformation in the production processes of camshafts. These systems eliminate the difficulties encountered with traditional manual processes, making production processes more efficient and error-free. The use of automated systems provides great improvements in production processes by offering high precision and accuracy at every stage. For example, processes such as cleaning, measurement, marking and assembly eliminate the need for manual intervention and perform processes faster and more reliably. In this way, both labor efficiency increases, and production times are shortened.

In addition, the integration of technologies such as automatic positioning, crescent gauge, laser marking and pin measurement systems continuously improve quality in production processes. These systems minimize waste and waste by ensuring the detection of faulty products at early stages. The detection and correction of faulty products reduces the costs in the production process and significantly increases product quality. The high accuracy rates of automatic measurement and control systems also guarantee full compliance of products with quality standards, which increases the compliance of end products with customer demands and industry standards.

Figure 21: Additive Manufacturing Section

These innovative solutions, in addition to increasing industrial efficiency, minimize errors in the production line and enable the production of high-quality products. Thanks to the developed systems, the margin of error in each production stage decreases and product quality increases. In addition, thanks to the integration of the systems, traceability is provided at each step in the production line, which increases the controllability of the quality of the products and the production processes. As a result, a significant increase is achieved in both quality control processes and overall production efficiency. As a result, these automatic control and measurement systems integrated into the production processes of camshafts provide companies with a competitive advantage and maximize industrial efficiency. The use of such technologies offers significant improvements not only in production processes, but also in areas such as quality control, labor management and cost optimization. The speed, accuracy and reliability provided by automated processes offer a faster, more efficient and error-free production process compared to traditional methods, which strengthens the companies' positions in market competition. In terms of long-term sustainability, the adoption of such innovative technologies is a critical step for the future of both companies and industry.

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CHAPTER 6

DIGITALIZATION OF THE DENTAL INDUSTRY - AN EXAMPLE FROM ESTAŞ R&D

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INTRODUCTION

Dentistry is a profession rich in materials. While many materials have lost their relevance over time, many new materials have entered the field of use. Alongside the ever-changing and growing variety of materials, the methods and techniques of production are also evolving day by day. The primary reasons for this change, in addition to technological advancements, are the increasing aesthetic expectations of patients and the consideration of factors such as ease of application, accuracy, and time by dentists. In prosthetic production, metal crowns produced by casting and dentures made by the flask method, which were once common practices, are now becoming less frequently used applications (SCHIERZ et al., 2024). Moreover, bridge restorations have begun to be replaced by implant treatments, and the rate of removable partial denture production has decreased, giving way mostly to fixed treatments. In the field of conservative treatment, composite fillings have replaced amalgam fillings, and in orthodontic treatments, brackets are slowly being replaced by clear aligner therapies. Additionally, with the scanning of patients' mouths through digital methods, fully digital designs and productions have become possible. Nowadays, aesthetic materials and digital production methods are much more popular, and advancements in this field are progressing rapidly.

The most significant development in the digital transformation of dentistry has been the introduction of CAD-CAM systems. CAD-CAM stands for "Computer-Aided Design-Computer-Aided Manufacturing." It refers to designing and manufacturing with the help of a computer. Initially used in the defense industry, CAD-CAM systems have been applied in dentistry since the 1980s. This system has enabled dentists to produce restorations that are faster, more precise, and more aesthetically pleasing. Through this technology, not only can the metal substructures of restorations be produced, but restorations can also be made from different dental materials (such as PMMA and zirconia)(Strub et al., 2006).

CAD/CAM systems used in dentistry are divided into two categories based on the production method: subtractive manufacturing and additive manufacturing. However, due to their widespread use in the dental field, when CAD/CAM is mentioned, it primarily refers to subtractive manufacturing (milling). This widespread use will change with advancing technology.

Subtractive manufacturing

Subtractive manufacturing is a prototyping and production process that involves removing unnecessary parts from a material to create an object. In the subtractive manufacturing method, the block material (ingot) is mechanically milled with cutting tools that can move along various axes, and the desired geometric shape is formed according to the computer's instructions. Today, various materials such as metals, resins, zirconia, and ceramics are used in this method. This technique is employed in dentistry for the production of inlays, onlays, veneers, implants, or tooth-supported fixed and removable prostheses, as well as diagnostic models (Spitznagel et al., 2018). Additionally, it can be used in orthodontics for producing clear aligners and in maxillofacial surgery for creating surgical guides used in implant procedures (Roberson & Sinha, 2022).

Figure 1. Computure aided manufacturing (CAM)

Additive manufacturing

As the name suggests, additive manufacturing adds materials to create an object and form its geometry. Additive manufacturing is also referred to as layered manufacturing, "3D printing," and "rapid prototyping." Through additive manufacturing, thermoplastic, metal, and biochemical materials can be produced (Chakravorty et al., 2024). The biggest advantage of additive

manufacturing compared to subtractive manufacturing is the significantly lower material loss (up to 40%), and it allows for finer details than those achievable with the cutting tools used in milling (Hofmann, 2014).

Figure 2. Selective Laser Melting Device

Figure 3. Co-Cr ceramic metal infrastructures produced by Selective Laser Melting.

Classification of Additive CAD/CAM Manufacturing Systems

1. Material Extrusion
2. Photopolymerization
    2.1. Stereolithography
    2.2. Digital Light Processing
    2.3. Powder Bed Fusion
3. Laser Sintering
    3.1. Direct Metal Laser Sintering- DMLS
    3.2. Selective Laser Melting
    3.3. Electron Beam Melting
4. Material Jetting and Binder Jetting
    4.1. Inkjet 3D Printing
    4.2. Multijet 3D Printing and Polyjet 3D Printing
5. Sheet Lamination

Stereolithography (SLA) and digital light processing (DLP) are the most commonly used additive manufacturing techniques in the field of dentistry. SLA consists of a pool of photopolymerisable liquid polymer, a platform on which the model is built, and an ultraviolet laser used to solidify the resin. First, a platform is created to stabilize the part and support any overhanging structures. The z-axis resolution, which refers to the thickness of each layer, is adjusted to 50 μm or less for applications that require high resolution. After the remaining uncured resin on the produced material is cleaned with a solvent, the material is placed in a UV oven for full polymerization (Zhang et al., 2019).

DLP printers operate on principles similar to SLA printers, with the main difference being the irradiation techniques. The design of DLP printers is similar to that of SLA printers. The primary difference is the light source. While SLA printers use a photopolymer light source, DLP printers utilize projection technology where short-wavelength light is directed via a digital micromirror device. As a result, DLP printers can cure the entire area with a single exposure using micromirrors, instead of scanning each area one by one with a laser as in SLA printers. This allows objects to be printed in a shorter

time, providing time savings. Since DLP printers use a shallower photopolymer resin vat compared to SLA printers, they generate less waste. Due to the pixel-based exposure in the DLP method, the resolution is higher. High-power LED sources are used, and the intensity of the light source can be controlled (Nayar et al., 2015).

With the advancing systems, 3D printing is now used in modern dentistry to produce personalized dental implants, maxillofacial implants and prostheses, fixed and removable prostheses, inlay and onlay restorations, occlusal splints, dental models, surgical guides, custom impression trays, guide models for tooth preparations, mock-up models, and orthodontic models and devices (Dawood et al., 2015; Sha et al., 2023).

3D printers used in dentistry must be fast, as systems that can deliver prostheses on the same day are desired. However, this speed should not come at the expense of surface quality. Accordingly, among the systems that can provide high surface quality, DLP technology stands out as the fastest method.

The DLP manufacturing method helps eliminate one of the biggest problems of our time, which is time loss, and allows for more precise and accurate productions as a result of digitalization.

With its established infrastructure and expert team, Estaş provides services in various fields, from design to rapid prototyping. Through the DLP additive manufacturing method, total prostheses, partial prostheses, crowns, and bridges can be produced. ESTAŞ, which works in various fields from design to rapid prototyping with its established infrastructure and expert team with FDM, DLP and SLM technology, which are among these additive manufacturing methods, serves many sectors from aviation to medical, automotive to defense industry

ESTAŞ has strengthened its production infrastructure with these devices by designing and producing DLP devices under the ESTECH brand, which have the ability to produce more precise and faster production compared to other additive manufacturing methods as a result of long-term R&D studies.

Figure 4. ESTECH brand DLP device.

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CHAPTER 7

CLEAR ALIGNERS

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INTRODUCTION

Clear Aligners

Clear aligners and similar appliances have been used for various purposes since the early 1900s. In general, clear aligner materials are non-inert resin polymers that are exposed to changes in temperature, humidity, chewing forces in the oral environment, and prolonged contact with saliva enzymes. Today, the most commonly used materials in the production of clear aligners are polyethylene, copolyester, polycarbonate, thermoplastic polyurethanes, and polypropylene. Most of the aligners on the market are made of modified polyethylene terephthalate glycol (PET-G), which is structurally amorphous and clear (Özay et all, 2022). Clear aligners can be shaped using the thermoforming method under heat and pressure, or they can be produced from 3D printer resins or through CAD-CAM technology.

Clear aligners are used in various fields of dentistry, including the treatment of bruxism and joint disorders, facilitating orthodontic tooth movements, teeth whitening applications, surgical stent and temporary tooth production, apnea appliance fabrication, and as protective gear for athletes.

Clear Aligners in Bruxism Treatment

Bruxism is an involuntary and parafunctional chewing system disorder that occurs in the form of teeth grinding or clenching during the day and while sleeping, leading to various adverse effects on the hard and soft tissues of the mouth. A night guard is the first treatment method that comes to mind for bruxism. Since the night guard is made of clear and slightly flexible material, it can be easily put on and taken off. When placed in the mouth, it significantly reduces the activity of the chewing muscles. It also distributes chewing pressure more evenly over the teeth, helping to control teeth grinding and clenching. The reduction in muscle activity allows the surrounding tissues to relax. Due to its regular use over a certain period, night guards promote muscle relaxation (Minakuchi et al.,2022)

Clear Aligners in the Treatment of Joint Disorders

Patients with joint disorders are often treated with a stabilization splint. The stabilization splint is used to determine where the imbalance in the joint chewing system occurs by altering the occlusion (bite) of the jaw and teeth to correct this imbalance. Due to its special design, the splint ensures proper occlusion between the upper and lower teeth and facilitates correct

functional movements. With the help of the splint, the chewing muscles, teeth, and jaw joint can work in harmony (Michelotti et al., 2020).

Protective sports aligners

Protective sports aligners, used during physical activity, help safeguard athletes against trauma and impact. Particularly for those involved in contact sports, the use of a mouthguard (sports aligner) is crucial in preventing serious oral and dental injuries. Dentists recommend sports aligners to minimize the damage caused by impacts in sports such as ice hockey, boxing, taekwondo, American football, soccer, and basketball (Roberts, 2023). While ready-made aligners are available, custom-made clear aligners can also be tailored to fit the individual.

Clear Aligners in Teeth Whitening Applications

Teeth whitening procedures are performed in two ways. The first method is applied by the dentist, while the second method allows patients to perform the procedure at home. In the home bleaching method, a model is made from impressions taken from the patient, and clear aligners are prepared to keep the whitening agent in contact with the teeth overnight. Patients can apply the whitening agent inside these aligners, allowing them to lighten the shade of their teeth (Haywood and Robinson, 1997).

Surgical Stent Fabrication and Clear Aligners

A stent is a device used for radiographic evaluation to assess the height and width of the available bone during implant treatment planning or surgical procedures. It helps ensure optimal implant placement by marking the precise location for the implant. Clear aligners can be used in the fabrication of these surgical stents, allowing for accuracy and ease of use during the procedure (Tack et al., 2016: Dawood et al., 2015)

Temporary Tooth Fabrication and Clear Aligners

When patients, especially those missing front teeth, require temporary restoration, acrylic or composite teeth are placed in the missing tooth area on a model, and a clear aligner is molded over it. This allows retention to be achieved by using the existing teeth in the mouth. In this way, the aesthetic temporary rehabilitation of the missing tooth area is made possible, providing an interim solution until permanent restoration is completed.

Snoring Appliances

Snoring appliances are oral devices designed to reduce or eliminate snoring by adjusting the position of the jaw and tongue during sleep. These devices, such as mandibular advancement splints (MAS), work by gently moving the lower jaw forward, which helps open the airway and reduces airway obstruction, one of the main causes of snoring.

Obstructive sleep apnea (OSAS) is a chronic disease with a high prevalence in population. It is becoming a significant social problem, since it is associated with a worsening in quality of life and increase in mortality. Sleep Laboratory Polysomnography (PSG) is the gold standard to diagnose snore and OSAS patients (Spencer et al., 2019).

For patients diagnosed with mild, moderate, or severe obstructive sleep apnea syndrome (OSAS), continuous positive airway pressure (CPAP) devices are commonly recommended (8). However, many patients refuse to use this device, and some struggle with its usage. An alternative treatment, the mandibular advancement splint (MAS), is an oral appliance that is easier to use and adapt to. MAS can be made from clear aligners or special 3D-printed splint resins, offering a more comfortable option for sleep apnea treatment.

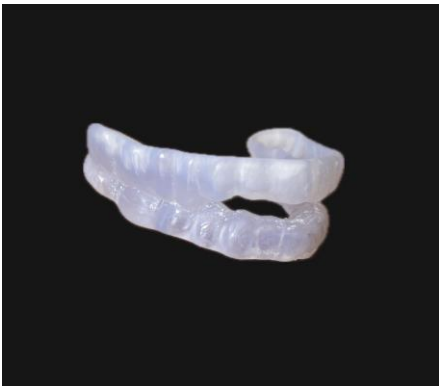


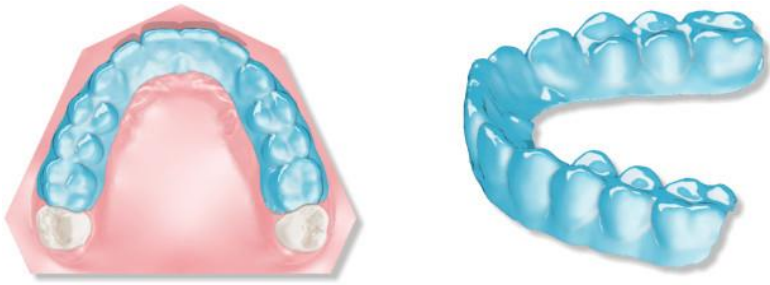
Figure 1. MAS (Mandibular advanced splint)

Orthodontic Treatments with Clear Aligners

The principle that small tooth movements could be achieved using thermoplastic clear appliances was first introduced by Kesling in 1945. This principle was later developed and utilized by many researchers. The pioneer of clear aligner technology, the Invisalign system, was theoretically defined

for the first time in 1997 by computer engineering students Zia Chisti and Kelsey Wirth. In the Invisalign system, instead of taking impressions and creating setups at each appointment, aligners are produced using 3D models obtained through computer-aided design (CAD) and computer-aided manufacturing (CAM) technology, which move the teeth. In this treatment method, where teeth can be corrected without traditional braces, patients wear the aligners for an average of 22 hours a day. Each aligner, produced in varying quantities depending on the case, is worn for a duration of 2 weeks. Once the aligners are fitted to the teeth, they begin to apply force, and each aligner usage results in an approximate movement of up to 0.5 mm in the teeth, facilitating their movement. With each change of aligner, new forces are applied, gradually aligning the teeth. With clear aligner treatment, it is possible to treat many orthodontic issues, such as severely crooked or spaced teeth, deep bites, or open bite problems (Tartaglia et al., 2021).

The designs of these orthodontic appliances can be created using the Maestro 3D software within the Estaş R&D department. During the design process, the desired movements to be applied to the teeth are clearly visualized through videos generated by the software.



Radiotherapy Prostheses

Patients who have undergone radiotherapy often experience side effects related to radiation. Particularly after radiotherapy in the head and neck region, common complications include radiation caries, dry mouth due

to the atrophy of salivary glands, mucosal inflammation, taste disturbances, difficulty swallowing, fibrosis, and osteoradionecrosis (Singh et al., 2021).

Figure 2. Radiation-protective plate

As Estaş Arge, we are conducting studies for the production of radiation-protective clear aligners. In the product planned for manufacture, different materials that can be custom-shaped (unique) using the thermoforming method are utilized, which can serve as radiation shielding. This aims to protect the teeth and surrounding tissues from radiation, effectively preventing radiation exposure or reducing its impact to a level that does not harm health. Tests conducted by TENMAK (Turkey Energy, Nuclear and Mineral Research Institute) have proven that the aligner blocks 99.9% of radiation, and studies have begun on topics such as scattering effects and treatment planning using phantom human models. Additionally, patent applications for the product have been submitted.

Table 1. Shielding values of radiation-protective plates

Kalite / *Quality*	**YG/***HV* **(kv)**	**Filtre /** *Filter*	**HVL (mm Al)**	**F_N / F_{IB}**	**Zayıflama /** *Attenuation* **%**	**Kurşun Eşdeğeri /** *Lead Equivalent*	**Belirsizlik /** *Uncertainty* **%**
NB60	60	2,5 mm Al	2,14	1.nokta : 1085,6	99,9	590,2 µm Pb	3,5
NB60	60	2,5 mm Al	2,14	2.nokta : 1080,4	99,9	589,5 µm Pb	3,5
NB80	80	2,5 mm Al	2,77	1.nokta : 116,6	99,1	598,1 µm Pb	3,5
NB80	80	2,5 mm Al	2,77	2.nokta : 116,2	99,1	597,3 µm Pb	3,5
IBB60	60	2,5 mm Al	2,14	760,8	99,8	548,8 µm Pb	3,5
IBB80	80	2,5 mm Al	2,77	105,2	99,0	631,7 µm Pb	3,5

Snoring appliances, aligners, and various clear aligners designed using the EXOCAD software within the Estaş R&D unit are manufactured using special resins in 3D printers. Similarly, plates for orthodontic tooth movements are designed with the MAESTRO 3D software and produced through 3D printing technology.

Estaş Doctor Application Panel

Thanks to the Estaş - Doctor Application Panel, patients can be registered, allowing for:

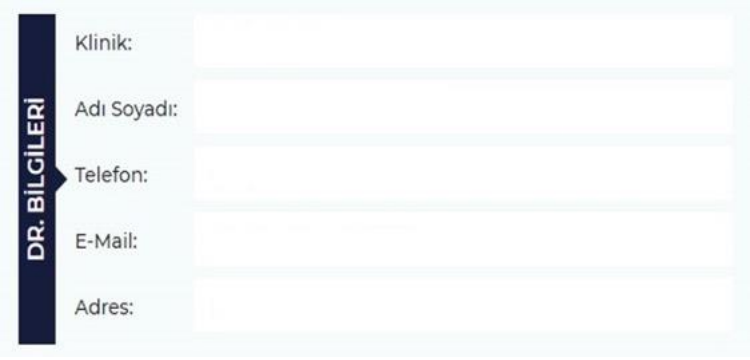
Patient records to be maintained

Patient data to be stored

Communication between patients and the laboratory to be facilitated

Tracking of the stage of the prosthesis to be managed

STL file transfer between the doctor and technician to be enabled




Hasta Kabul Ve İletişim Formu
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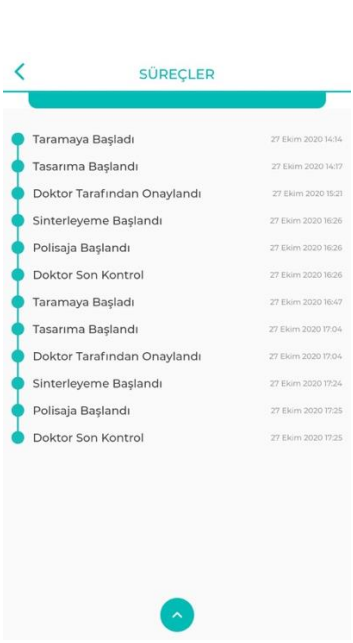
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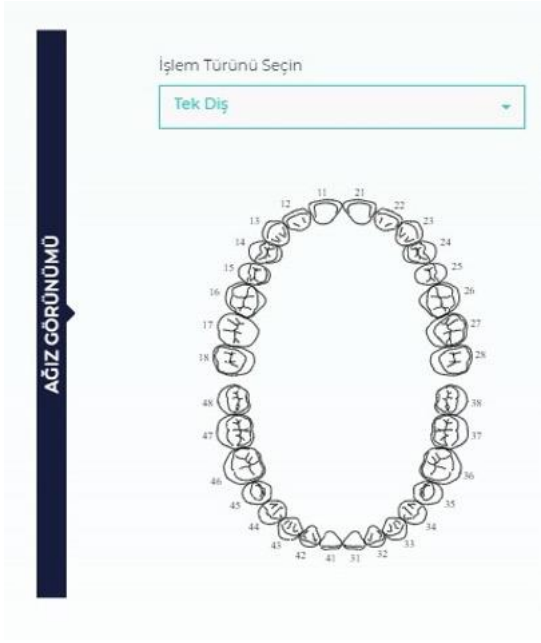
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CHAPTER 8

PERIPHERAL VASCULAR DISEASES

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INTRODUCTION

Cardiovascular diseases are still the leading cause of death today (Woodruff et al., 2024). Research predicts that this situation will continue in the same way in 2030 (World Health Organization [WHO], 2021). In fact, cardiovascular system-related deaths are by far the leading cause of death worldwide, when natural disasters, accidents, and wars are also taken into account. Cardiovascular system diseases are at the leading cause of death, as well as being the leading cause of morbidity such as emergency hospital admissions, limb losses due to circulatory system disorders, and strokes. So much so that heart attacks are not only the cause of death but also lead to heart failure. Carotid artery diseases are also the leading cause of stroke. Another main issue is peripheral artery diseases, in which the number of deaths is high, but limb losses are more prominent. Especially when familial factors are added to the increase in risk factors such as diabetes, hypertension, tobacco use, alcohol use, high cholesterol, and sedentary lifestyle, which have become more common today, peripheral artery diseases seem like an inevitable outcome. For many years, the treatment of these diseases primarily involved medical (anticoagulant and antiplatelet therapies) and surgical (bypasses, embolectomy, thrombectomy, endarterectomy, etc.) options. However, with technological advancements, the inclusion of endovascular interventional methods in these treatment options has significantly altered the course of peripheral artery diseases. The introduction of stents and balloon angioplasty, techniques initially used in coronary artery diseases, into the treatment of peripheral artery diseases has provided patients with significant comfort and unparalleled ease. The use of stents and balloons in peripheral artery diseases does not date back very far; the history of endovascular interventions began approximately 30 years ago (Medical Advisory Secretariat, 2010). The past 30 years have witnessed significant milestones in endovascular interventions, and endovascular interventions are now becoming the first choice for treating peripheral vascular diseases. Looking ahead, it seems likely that many lesions, which are currently considered difficult or impossible to treat interventionally, will become treatable. As technology advances, not only are these diseases being managed, but there is also a growing need for new markets and resources from companies developing these technologies. The most critical of these resources is the collaboration between experts in R&D, specialists in this field, and institutions that are willing and able to invest in R&D efforts. Theoretically, if the right institutions are matched with the right individuals,

technological advancements will progress more rapidly and in accordance with established guidelines. ESTAŞ, a company based in Sivas, exemplifies such an institution, possessing these critical qualities. By collaborating with faculty members who are experts in their fields, ESTAŞ has gained a pioneering and dynamic edge in R&D, pushing the boundaries of innovation (ESTAŞ Medikal, 2024). The projects we have conducted with ESTAŞ, most of which are nearing completion, include "the design and production of an aspiration catheter for use in the aspiration of bodily secretions", "the design and production of a drip control set for the regulated administration of IV fluids in intensive care units", "the design and production of a Y-connector system for different fluid applications through a single vascular access in cardiovascular and thoracic surgery procedures", and "the design and production of a manifold set used in angiography and PTCA procedures".

1. RISK FACTORS AND EPIDEMIOLOGY OF PERIPHERAL VASCULAR DISEASE

The most common upper extremity arterial diseases are subclavian artery stenosis and occlusions. These conditions occur in approximately 2% of the general population, 5% of patients who have undergone coronary artery bypass surgery, and 10% of those with lower extremity arterial disease (Abdul Jabbar et al., 2017; Aboyans et al., 2018; Saha, Naqvi, Ayah, McCormick & Golgberg, 2017). Lower extremity arterial diseases are present in approximately 18% of individuals under the age of 65, and this prevalence increases to about 20% in those over 65 (Aboyans et al., 2018; Campia, Gerhard-Herman, Piazza & Goldhaber, 2019). Diabetes is the leading risk factor for peripheral artery disease (PAD). As the duration of diabetes increases, it leads to endothelial dysfunction, which ultimately results in atherosclerosis (Thiruvoipati, Kielhorn & Armstrong, 2015). Patients on oral antidiabetic medications or insulin therapy are at significant risk for PAD if their blood sugar levels are not well-regulated. Hyperlipidemia is another critical risk factor for PAD. Conditions such as hypercholesterolemia, hypertriglyceridemia, or combined/mixed forms of dyslipidemia are among the primary factors that increase susceptibility to PAD. Lipid levels should be carefully controlled with lipid-regulating agents like statins and fenofibrates (Belur, Shah, Virani, Vorla & Kalra, 2022). Patients with hypertension also fall into a high-risk group for PAD. The primary mechanism of hypertension is the loss of vascular endothelial elasticity, which stems from atherosclerosis (Clement, 2020). Therefore, every hypertensive patient is inherently a

candidate for atherosclerotic vascular disease. It is crucial not to neglect antihypertensive treatment, and patients should adhere to a diet that helps prevent hypertension. Another high-risk group includes patients with hyperhomocysteinemia, a condition known to predispose individuals to atherosclerosis (Liu et al., 2020). Hyperhomocysteinemia affects approximately 5-7% of the population, and these patients benefit from homocysteine-lowering therapies and vitamin B12 supplementation. Genetic predisposition is also a risk factor for PAD. A poor genetic inheritance is an unmodifiable risk factor for PAD (Kristensen et al., 2017). Additionally, there are modifiable risk factors such as smoking, alcohol and substance abuse, exposure to certain chemicals, and obesity (Hwang, Muchira, Hibner, Phillips & Piano, 2022; Miao et al., 2024; Wang et al., 2024).

2. COURSE OF PERIPHERAL VASCULAR DISEASE

In the course of peripheral vascular disease (PVD), aside from treatment, there are two critical outcomes to consider. The most severe outcome, mortality, has been found to occur at a rate of 40.1% over an 8-year follow-up period, which demonstrates that PVD can be more lethal than many well-known cancers (Gunnarsson, Gottsäter, Bergman, Troëng & Lindgren, 2020). Amputation rates have been reported to be between 15-20% within a 1-year follow-up (Barnes, Eid, Creager & Goodney, 2020). Among patients who have undergone amputation, the mortality rates at 1, 2, 3, and 5 years are 47.9%, 61.3%, 70.6%, and 62.2%, respectively (Stern et al., 2017).

3. DIAGNOSIS OF PERIPHERAL VASCULAR DISEASE

As with any disease, diagnosis begins with a thorough history and physical examination. Key questions include the duration of the disease, the affected extremity, the nature of the pain, its relationship to rest, and how it impacts walking distance. These inquiries, combined with a physical examination, can lead to a diagnosis in 90-95% of cases (Figures 1A, 1B). However, after establishing a diagnosis, additional tests may be necessary to guide the treatment plan. For example, while a simple stenosis might be managed with medical therapy, more severe stenoses may require endovascular, surgical, or hybrid approaches. Diagnostic tools such as color Doppler ultrasonography, ankle-brachial index measurement, direct arteriography, contrast-enhanced magnetic resonance imaging, and contrast-enhanced computed tomography are employed based on the individual patient and can help direct appropriate treatment.

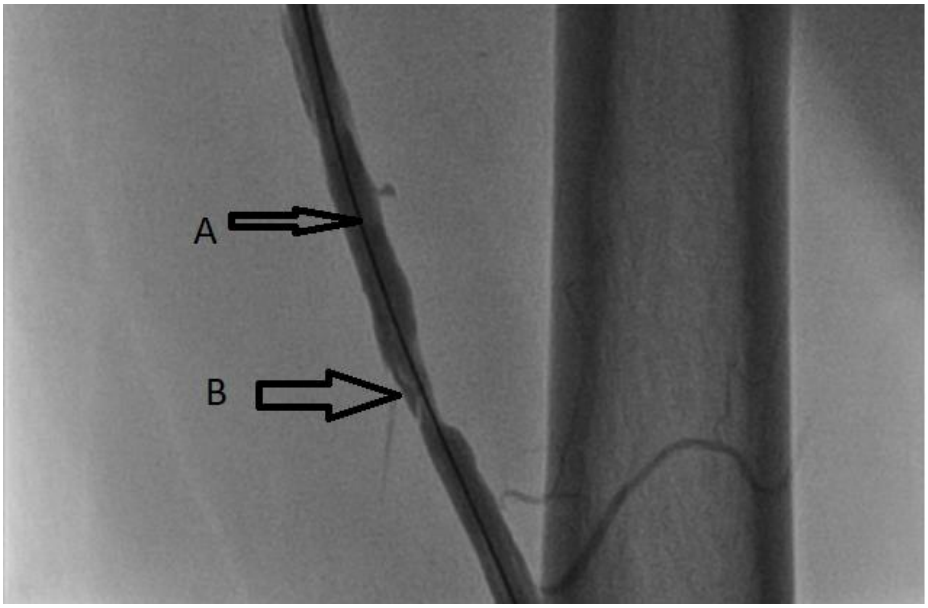

Figure 1A. A) Hydrophilic guidewire used in endovascular interventions. B) Stenosis observed in the superficial femoral artery.
Source: Assoc. Prof. Dr. Fatih ADA's archive.

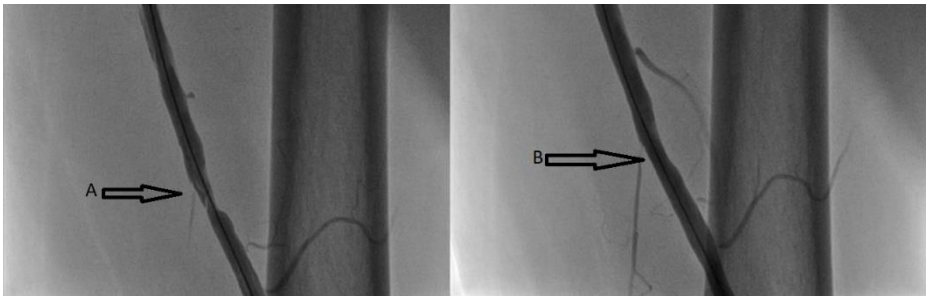

Figure 1B. A) Pre-procedural stenosis in the superficial femoral artery. B) Note the improved vessel surface following balloon angioplasty (percutaneous transluminal angioplasty, PTA).
Source: Assoc. Prof. Dr. Fatih ADA's archive.

4. TREATMENT OF PERIPHERAL VASCULAR DISEASE

The treatment of peripheral artery disease (PAD) can be primarily divided into three categories. Although hybrid and combined therapies are becoming more common and may be considered as separate categories in the future, for now, the therapy options are classified as follows:

- Medical therapy
- Endovascular therapy
- Surgical therapy

4.1. Medical Therapy

In the primary treatment of PAD, medical therapy can be utilized either as a stand-alone approach or as an adjunct to endovascular or surgical treatments. A wide range of treatment options includes oral anticoagulants, antiplatelet agents, new oral anticoagulants, low molecular weight heparins, dual antiplatelet therapy, ACE inhibitors, beta blockers, statins, fenofibrates, cilostazol, and iloprost. However, patients may receive a combination of these therapies or be treated with only one or a few of them.

4.2. Endovascular Therapy

In modern practice, endovascular therapies for peripheral artery disease (PAD) are increasingly becoming the standard for diagnosis, treatment, and therapeutic interventions. These methods are frequently used for diagnosing and treating diseases affecting the lower extremities, upper extremities, neck vessels, aorta, and visceral arteries. Endovascular treatments are typically performed under local anesthesia, without sedation, which reduces the risk of anesthetic complications and provides significant advantages such as no incision, no need for general anesthesia, early mobilization, and quicker discharge, allowing for a faster return to social activities. Endovascular procedures are conducted under fluoroscopy. These procedures can be performed in specially designed hybrid labs, or any unit equipped with angiography facilities. The targeted area is first sterilized and marked, then numbed with a local anesthetic. A puncture needle is used to access the vessel, and images are obtained. After evaluating these images, the appropriate course of action for the procedure is determined. Depending on the condition of the vessel during the procedure, treatments may include PTA, stenting, or a combination of PTA and stenting (PTA+stent) (Figures 2 and 3). After the procedure, pressure is applied to the puncture site to minimize bleeding risks.

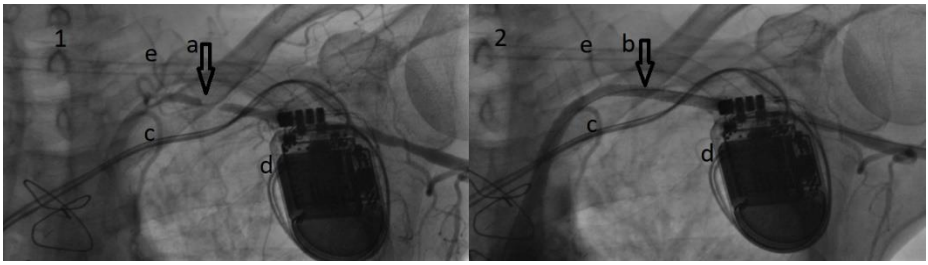

Figure 2. 1: Pre-procedure 2: Post-procedure a: Note the 99% stenosis in the left subclavian artery before the procedure. b: Observe the complete resolution of stenosis in the region after stenting. c: LIMA artery supplying the LAD in a patient with a coronary bypass. d: Cardiac pacemaker and electrodes. e: Vertebral artery branching from the left subclavian artery.
Source: Assoc. Prof. Dr. Fatih ADA's archive.

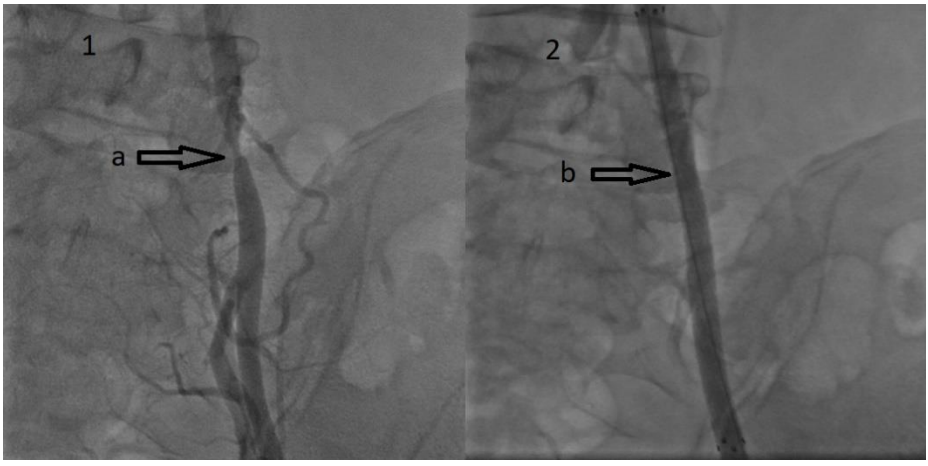

Figure 3. 1: Pre-procedure 2: Post-procedure a: Note the 90% stenosis in the left common iliac artery before the procedure. b: Note the complete resolution of stenosis in the region after stenting.
Source: Assoc. Prof. Dr. Fatih ADA's archive.

4.3. Surgical Therapy

Despite advancements in medical and endovascular treatments, surgical options will remain necessary as long as humanity exists. Difficult lesions, complications during endovascular procedures, and cases that do not respond to endovascular treatment will always be present. Therefore, surgical treatment will continually evolve and remain relevant. The main focus of surgical treatment is to ensure that arterial blood flow reaches the distal segment beyond the stenosis or occlusion without obstruction. This is

achieved by either bypassing the stenotic or occlusive segment or removing the causative structure

(endarterectomy, thrombectomy, thromboendarterectomy).

Endarterectomy, thrombectomy, and thromboendarterectomy are primarily preferred methods for acute conditions, while bypass surgery is more commonly utilized for chronic cases. Another important consideration in peripheral artery bypass is the choice of graft to be used. Two approaches are considered for graft selection in peripheral artery bypass. The first approach is the use of autogenous grafts, such as the saphenous vein or other venous/arterial structures, in patients with suitable vascular anatomy. The second approach involves the use of synthetic grafts, such as Dacron or PTFE. The choice and quality of the graft used depend on factors such as the patient's structural risk factors, age, comorbidities, and life expectancy (Figure 4).

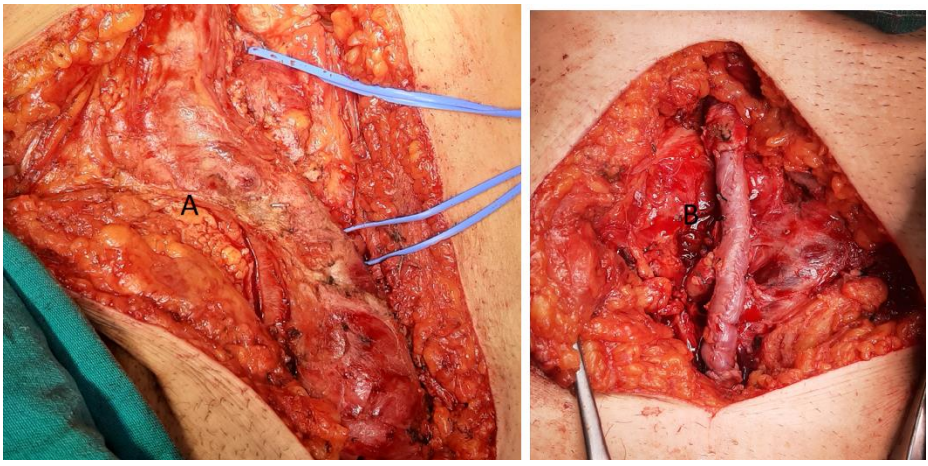

Figure 4. A: A thrombosed aneurysmal sac involving the common, superficial, and profunda femoral arteries, illustrating its contribution to peripheral vascular disease. B: Appearance after autogenous graft surgery with saphenous vein reconstruction. Note the compatibility of the vascular structures.
Source: Assoc. Prof. Dr. Fatih ADA's archive.

CONCLUSION

Peripheral vascular diseases should be given serious attention and all available therapy options should be fully utilized due to their significant contribution to both mortality and morbidity. The most promising aspect is the expectation of a reduction in mortality and morbidity rates in the coming

years through innovative technologies and advancements. In countries like Türkiye, which are continuing industrial advancements, the contributions of companies like ESTAŞ, which push the boundaries of R&D to develop innovative products, are a source of pride and satisfaction.

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CHAPTER 9

ORTHOPEDICS AND TRAUMATOLOGY RESEARCH AND DEVELOPMENT

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INTRODUCTION

The average cost of orthopedic surgeries in the United States is quite high. For instance, the cost of hip replacement surgeries ranges between 30,000 and 50,000 USD, whereas in Europe, this cost is between 15,000 and 25,000 EUR (AAOS, 2023). This cost difference arises from the use of advanced medical technologies and the structure of healthcare pricing (1).

Globally, the total market size of orthopedic and traumatology implants was approximately 55 billion USD in 2022 and is expected to reach 73 billion USD by 2028 (2). This increase is associated with the aging global population and rising demand for surgical procedures.

ESTAŞ Medical was established in 2015 in Sivas, Turkey, focusing on the production of implants in orthopedics and traumatology. Initially concentrating on the design and production of diaphyseal and arthrodesis prostheses used in the treatment of bone tumors, the company quickly expanded its product range to include various items used in neurosurgery and maxillofacial surgery (3).

With its R&D and innovation-oriented approach, ESTAŞ Medical places great importance on university-industry collaborations. The company strengthens these collaborations through joint projects, intellectual property, publications, and clinical studies with expert academics (3).

The goals of ESTAŞ Medical include increasing employment of R&D personnel and skilled workforce, enhancing production capacity and efficiency, improving product quality and standards, and designing and manufacturing personalized implants.

R&D ACTIVITIES

Diaphyseal Arthrodesis Systems

These systems are used in cases of bone tumors requiring diaphyseal resection and in aseptic or infected knee prosthesis loosening that cannot be revised (3).

Figure 1: Components of the diaphyseal arthrodesis system (3)

Orthopedic Trauma Systems

Figure 2. Anatomical titanium plate and screw systems (3).

Figure 3. Headless screw systems of various diameters and lengths (3).

Figure 4. External fixator systems (3)

Figure 5. Cable systems (3).

Clinical Evaluation of Moment Tumor Hip Prosthesis Products

This study is a multicenter, prospective, local medical device clinical trial. The study duration is six months and will continue until the target sample size, determined by power analysis, is reached. Since the intervention involves surgery, it is performed only once, and patients will be followed for six months from the day of surgery. The study is designed as a prospective cohort study with a cross-sectional evaluation approach.

The clinical research on the tumor prosthesis, designed by Prof. Dr. Mehmet Ayvaz from Hacettepe University Faculty of Medicine, is being carried out under the coordination of Prof. Dr. Zekeriya Öztemür at Sivas Cumhuriyet University Department of Orthopedics and Traumatology across seven universities.

Figure 6. Moment hip tumor prosthesis (3).

Universities involved in the project:

1. Sivas Cumhuriyet University Faculty of Medicine
2. Necmettin Erbakan University Meram Faculty of Medicine
3. Gazi University Faculty of Medicine
4. Pamukkale University Faculty of Medicine
5. Istanbul Göztepe Prof. Dr. Süleyman Yalçın City Hospital

6. Eskişehir Osmangazi University Faculty of Medicine
7. Hacettepe University Faculty of Medicine

Theses and Scientific Activities Supported by ESTAŞ

A. Histological and SEM Investigation of the Effects of Titanium Surface Modifications on Osseointegration in Rabbits. Aydın B, Supervisor: Prof. Dr. Zekeriya Öztemür, Sivas, 2022, Thesis.

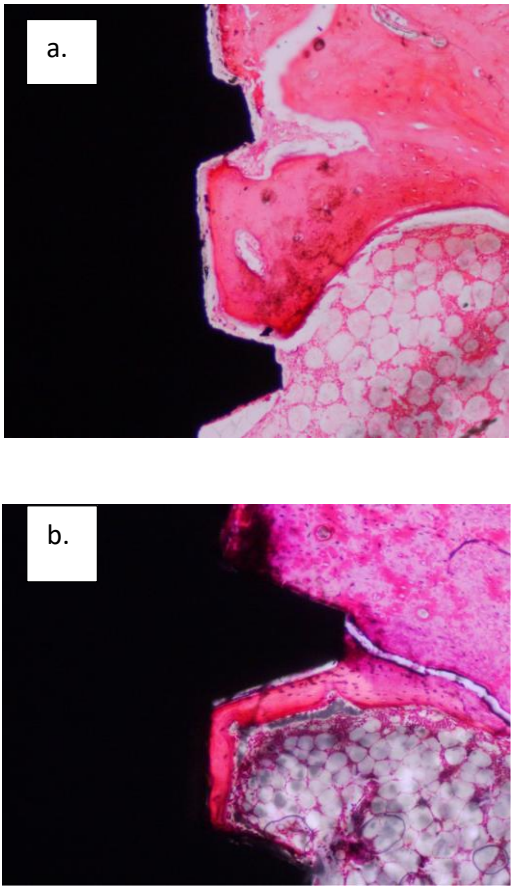

Figure 7. SEM images showing new bone formation on screw surfaces modified by chemical roughening and EMA (a surface modification defined by ESTAŞ Medical).

ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA
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Research Article

Histological and scanning electron microscopy investigation of the effects of titanium surface modifications on osseointegration in rabbits

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ABSTRACT

Objective: This study aimed to compare the novel Estaş Medical Anodization (EMA) surface treatment technique with the techniques commonly used in the literature and to examine their effects on osteointegration in the rabbit tibia.

Methods: A total of 24 rabbits used in this study were divided into 3 groups, with 8 rabbits in each group. Using both tibias of all rabbits in the study, screws belonging to the control group were placed in the left tibia, and the right tibia belonging to the experimental group were placed. In the first 8 rabbits, a single experimental group in the right tibia were used; in the second 8 rabbits, 2 different experimental groups in the right tibia were used; and in the last 8 rabbits, 2 different experimental groups in the right tibia were used. Thus, 5 different experimental groups with 8 screws in each group and a separate control group were formed for each of them. EMA-treated surfaces were named 200-800 nm iris oxidation and 800-1200 nm gray oxidation according to the TiO_2 layer thickness. Group 1 was implanted with mini-screws prepared with chemical etching+EMA iris oxidation, while group 2 was implanted with sandblasted, large-grit and acid-etched (SLA) mini screws treated with EMA gray oxidation. Group 3 was implanted with mini-screws treated with EMA gray oxidation, group 4 was implanted with mini-screws treated with chemical etching+micro-arc oxidation, and group 5 was implanted with mini-screws treated with chemical etching+EMA gray oxidation. The control group was implanted with mini-screws prepared with pure titanium. At the end of 6 weeks, osseointegration percentages were calculated and compared using histological and scanning electron microscope (SEM) analyses.

Results: The histological results confirmed the increase in osseointegration percentages in all experimental groups compared to those that received pure titanium implants (*P* values control group vs group 1=.005, control group vs group 2, 3, 4, 5=.001). The comparison between the groups revealed that the chemical etching+EMA gray oxidation modification technique (group 5) significantly increased osseointegration compared to the SLA+EMA gray oxidation technique (group 5 vs group 2 *P*=.016) and the chemical etching+EMA iris oxidation technique (group 5 vs group 1 *P*=.001). The EMA gray oxidation technique (group 3) significantly increased osseointegration compared to the chemical etching+EMA iris oxidation technique (group 1) (group 3 vs group 1 *P*=.043). The results of the SEM analysis showed that osseointegration was significantly increased in all experimental groups compared to that in the pure titanium (control) group (*P* values control group vs group 1, 2, 3=.001, control group vs Group 4,5=.006). The mean osseointegration percentage in the experimental groups was the highest in group 5, followed by group 4, group 3 and group 1 equally, and group 2. However, the differences among the experimental were not significant (group 1, group 2, group 3, group 4 vs group 5 *P*=.408).

Conclusion: The EMA titanium surface modification techniques we developed significantly increased osseointegration compared to the pure titanium surface. The EMA gray oxidation technique seems to result in higher osseointegration rates than the EMA iris oxidation technique, and similar rates can be found with the SLA and chemical etching techniques.

Level of Evidence: N/A.

B. Biomechanical Comparison of Fixations with Endobutton and Anchor Screws for Patellar Fixation in Medial Patellofemoral Ligament Reconstruction. Yağan T, Supervisor: Prof. Dr. Zekeriya Öztemür, Thesis, 2024 (6).

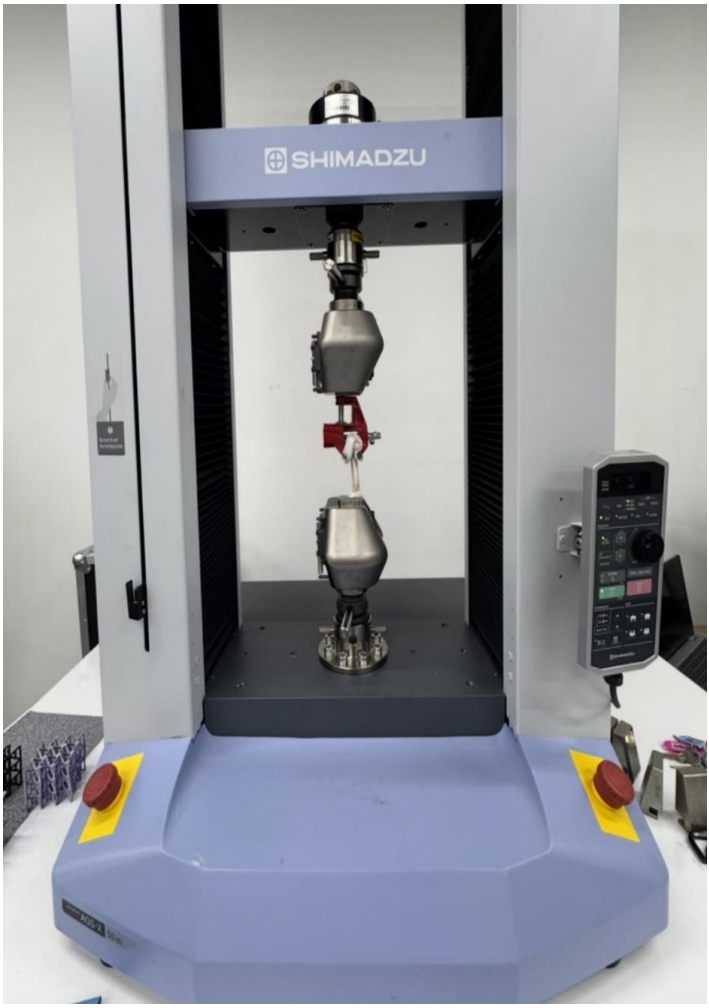

Figure 8. Shimadzu AGS-X 50 kN tensile testing device (6)

Patents

Syndesmosis plate and screw system used in tibia, talus, and fibula bone deformities.

TÜRK PATENT
TÜRK PATENT VE MARKA KURUMU

FAYDALI MODEL BELGESİ

No: TR 2020 10118 Y

Buluş Başlığı

Tibia, Talus ve Fibula Kemik Deformasyonlarında Kullanılan Syndesmosis Plak ve Vida Sistemi

Faydalı Model Sahibi

ESTAŞ EKSANTRİK SANAYİ VE TİCARET ANONİM ŞİRKETİ

ZEKERİYA ÖZTEMÜR

Bu belge, 6769 sayılı Sınai Mülkiyet Kanunu kapsamında 26/06/2020 tarihinden itibaren 10 yıl süre ile korunmak üzere 21/04/2022 tarihinde verilmiştir.

Cemil BAŞPINAR
Kurum Başkan V.

Figure 9. Utility model certificate (7).

Meetings and scientific conferences supported by ESTAŞ

On September 6, 2024, an important scientific meeting was held in collaboration between the Department of Orthopedics and Traumatology at Sivas Cumhuriyet University and the Turkish Society of Sports Traumatology, Arthroscopy, and Knee Surgery.

Hosted by Sivas Cumhuriyet University, the event brought together academics, healthcare professionals, and medical students from across Turkey. The meeting focused on the latest developments and innovations in sports injuries, arthroscopic surgery, and traumatology.

The opening speech was delivered by Prof. Dr. Zekeriya Öztemür, Head of the Department of Orthopedics and Traumatology at Sivas Cumhuriyet University, who welcomed the participants and emphasized the importance of scientific collaboration. Throughout the day, sessions featuring presentations by leading experts in the field attracted significant interest.

The event not only contributed to the professional development of young physicians and students but also provided a platform for fostering new collaborations in orthopedics and traumatology. Participants expressed their satisfaction with the meeting, highlighting its value in sharing scientific knowledge and experiences

Ongoing R&D Projects

1. Retrograde femoral nail design
2. Proximal femoral nail design
3. Anchor design

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6.Biomechanical Comparison of Fixations with Endobutton and Anchor Screws for Patellar Fixation in Medial Patellofemoral Ligament Reconstruction. Yağan T, Supervisor: Prof. Dr. Zekeriya Öztemür, Thesis, 2024

6.Türk patent Utility model certificate No: TR 202010118Y

CHAPTER 10

SCREWS AND PLATES USED IN VETERINARY ORTHOPEDICS

İlker ŞEN[1]

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INTRODUCTION

The incidence of musculoskeletal system injuries in pets is quite high, and fractures account for approximately 17.80% of small animal surgery cases. Among all fractures, long bone fractures are seen in about 84.48% of cases (Ali, 2013). The goals of fracture treatment are to promote healing and restore the function of the affected bone and soft tissue with a cosmetically acceptable appearance (Johnson & Hulse, 2013). These goals can be achieved through rigid internal fixation, atraumatic tissue management, and early joint movement (McLain & Brown, 1982,Fossum, 2007). Three systems can be applied for the stabilization of long bone fractures: intramedullary implants, external fixators, and combinations of bone plates and screws (Gemmill, 2007). Among internal fixation techniques, the use of bone plates is quite common. Bone plates have the potential to provide rigid stabilization to the reconstructed fracture and effectively resist axial load, bending, and rotational forces acting on the fractured bones (Sateesh Kumar et al., 2019).

When placing a plate on the fracture line for stabilization, many factors must be considered. In selecting the type and size of the plate, the patient's weight, the dimensions of the bone to be operated on, the size of the fracture fragments, the method of application, and the expected weight stresses in the area should all be taken into account. The AO group has developed guideline recommendations for plate size selection for various bones based on the patient's weight. These guidelines provide practical information that surgeons can use to select the most appropriate plate for their patients, thus offering the maximum chance for stability and healing with the applied treatment (Tobias & Johnston, 2012).

Since the structure of bones in animals is rarely flat, most plates need to be reshaped to fit the surface. Plate benders and presses are used for the bending of plates (Fossum, 2007; Tobias & Johnston, 2012).

The mechanical aspects of the forces acting on the fracture line and how they affect the bone must be considered when determining the location for plate application. If a bone has a primary bending direction, it is most appropriate to place the plate on the bone surface where tension occurs. If the bone reduction is performed in this way, the moment of inertia of the reduced bone is added to that of the plate, making the entire reduction much stronger. This method ensures that both the plate and the bone become more resistant to bending forces (Tobias & Johnston, 2012).

1. SCREWS AND PLATE SCREWS

1.1. Cortical and Cancellous Screws

There are different types of bone screws routinely used in veterinary orthopedics. The primary distinction between these screws is based on the type of thread they have. Screws designed for use in cortical bone, which has relatively higher density, have threads that are more closely spaced (shorter distance between threads) and less deep compared to screws intended to anchor in cancellous bone (Figure 1) (Tobias & Johnston, 2012). Additionally, there are locking screws with threaded heads that are designed to be used with appropriate locking plates, available with both cortical and cancellous thread spacing (Figure 2).

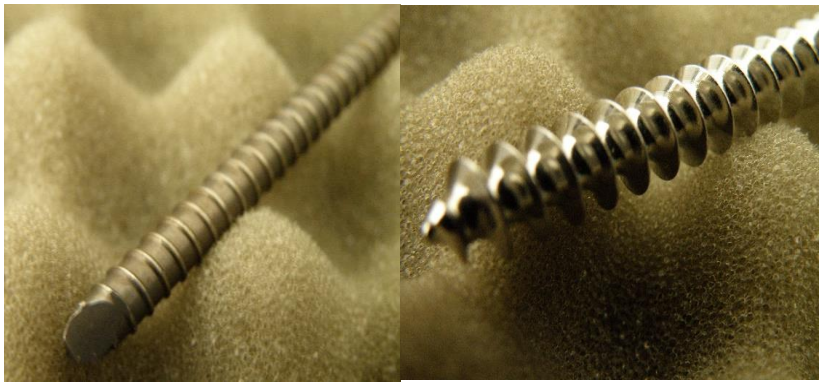

Figure 1: Cortical (Left) and cancellous (Right) screws.

Self-tapping screws are designed to speed up the screw insertion process. The cutting notch at the tip allows the screw to position itself by creating a thread pattern in the bone without requiring the use of a tap. The presence of the cutting notch reduces the overall surface area of the bone-screw interface; therefore, to achieve similar holding strength, the screw must fully pass through the far cortex. This technical detail becomes particularly important when applying screws to osteoporotic bone. When the screw tip is applied to extend 2 mm beyond the far to cortex, the mechanical properties of self-tapping screws become equivalent to those of traditional cortical screws. One study reported that the use of self-tapping screws in plate fixation reduced the complication of screw loosening (Canzemius & Swainson, 1999; Tobias & Johnston, 2012).

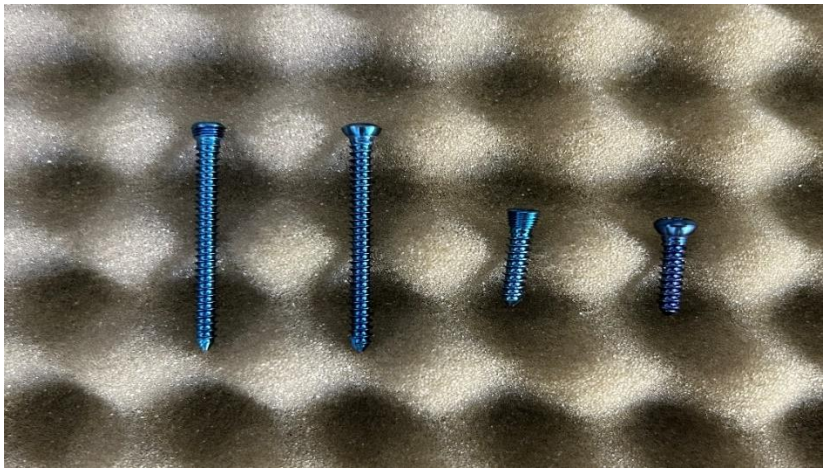

Figure 2: Veterinary locking and non-locking cortical screws.

Standard diameters for cortical or cancellous screws are 1.5, 2.0, 2.4, 2.7, 3.5, 4.0, 4.5, 5.5, and 6.5 mm. Screws can be manufactured in different lengths for each diameter. Like other implants, the screws are made from 316L stainless steel or titanium alloy. Although titanium screws are produced in various sizes and diameters similar to stainless steel screws, they are primarily designed to be used with titanium plates (Canzemius & Swainson, 1999).

1.2. Lag Screw

Another commonly used term related to screws is the "lag" screw. Essentially, this is not a type of screw, but rather an effect created by the screw. All screws can be used as lag screws. For example, when using standard screw insertion techniques, half-threaded cancellous screws create a lag effect as long as the threads of the screw only grip the far fracture fragment (Figure 3). As the screw is tightened and advanced, the head of the screw contacts the near cortex, and during the compression process, the longitudinal movement of the screw causes the two fragments to come closer together, ultimately resulting in interfragmentary compression. The lag effect can be achieved either by using half-threaded screws or by creating a channel in the near cortex that is larger than the screw's diameter or the core diameter but smaller than the screw head diameter. This prevents the screw threads from gripping the bone in the near fragment as the screw is inserted. This channel is called a "gliding hole." In the far fragment, the standard screw application techniques are followed, and interfragmentary compression is

achieved by tightening the screw as it advances through both channels (Canzemius & Swainson, 1999; Tobias & Johnston, 2012).

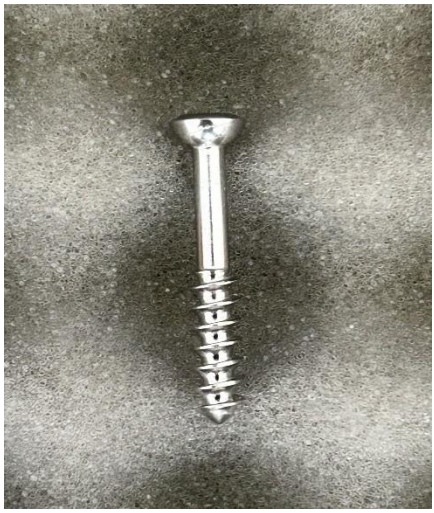

Figure 3: Half-threaded cancellous lag screw.

1.3. Shaft Screw

A shaft screw also creates a lag effect. Unlike a half-threaded cancellous screw, a shaft screw has an unthreaded portion with the same diameter as the threaded portion, and its thread profile matches that of a cortical screw. These screws are used as lag screws in diaphyseal fractures (Tobias & Johnston, 2012).

1.4. Cannulated Screw

Cannulated screws are designed for closed reduction. These screws have a hole running through their shaft. A Kirschner wire is used to maintain the reduction, and the screw is placed over the wire, advancing along the wire as it is screwed into the bone (Canzemius & Swainson, 1999; Tobias & Johnston, 2012).

1.5. Positional Screw

A positional screw is used to hold fragments in a specific position. Its threads are placed to engage both the near and far fragments. This method provides much less stable fixation compared to compression-based fixation. If compression would cause the bone fragments to collapse onto each other, the screw may need to be placed as a positional screw. This technique is

particularly applicable for complicated intra-articular fractures (Tobias & Johnston, 2012).

2. BONE PLATES

Bone plates are primarily made from 316L stainless steel and titanium alloy. Plates are manufactured in various sizes and shapes depending on the location of application and the required strength. Many manufacturers produce plate and screw systems based on the original systems developed by the AO/ASIF group. Some of these systems have been specifically developed for the veterinary market (Canzemius & Swainson, 1999; Tobias & Johnston, 2012; Ayyappan, 2013).

Applying the plate to the tension surface of the fractured bone creates interfragmentary compression when the animal bears weight on the limb, and this compression force is cyclical due to the nature of walking. For example, the tension surface on the femur is lateral, and when the bone is loaded eccentrically, the fracture site tends to "close." During a step, the plate is under tension. This cyclical loading causes tension on the plate and compression at the fracture site with each step the animal takes. This process supports fracture healing while also providing natural stabilization to the bone (Ayyappan, 2013).

Selecting the appropriate plate size for treatment is crucial and should be done with care. Generally, the width of the plate should be about 75% of the bone diameter. For supportive or bridging functions, wider plates may be utilized. The length of the plate should permit the placement of at least three screws in the bone fragments on both sides of the fracture. In cases involving osteoporotic bones, younger or larger animals, or when increased loading is anticipated, longer plates are recommended. Typically, it is advised that a substantial portion of the bone length be covered by the plate. Plates must be pre-shaped to fit the bone surface closely; greater contact between the plate and bone enhances stability during reduction and fixation. If the plate is improperly shaped, tightening the screws may lead to loss of reduction, which is particularly critical in intra-articular fractures (e.g., acetabular fractures). Another essential principle in shaping plates, especially compression plates, is "pre-stressing." When plates are contoured closely to the bone and placed under tension, they only make contact with a small area of the bone (typically less than 20%). Consequently, this can result in asymmetric compression between the fracture fragments. While the fracture line beneath the plate

experiences compression, the distance between the fragments on the opposite cortex may increase. Such limited contact means the plate must bear all the loads, thus stabilizing the fracture with minimal support from the bone. Numerous studies have indicated that pre-stressing the plate can help eliminate the gap on the opposite cortex, thereby enhancing fracture stabilization. This pre-stressing is accomplished by gently bending the plate inward, which creates a small gap (1.0–2.0 mm) between the bone and plate at the fracture site. This technique compresses not only the cortex in contact with the plate but also the opposite cortex. Plate shaping is performed using handheld plate benders or a plate bending press, and bending irons may also be employed to rotate the plate around its longitudinal axis. Plates should be bent or rotated in smooth curves, as abrupt directional changes may not conform adequately to the bone surface and can lead to poor contact between the bone and plate. If feasible, it is preferable to bend the plate between the screw holes rather than directly above them. This approach minimizes the risk of plastic deformations that could lead to metal fatigue in the plate, thereby preserving the strength of the implant (Canzemius & Swainson, 1999; Ayyappan, 2013).

2.1. Dynamic Compression Plates (DCP) and Limited Contact Dynamic Compression Plates (LC-DCP)

The goal of fracture management is to anatomically reconstruct the fractured limb and restore movement to the affected limb as early as possible. The dynamic compression plate (DCP), developed by the AO group, is a specialized plate designed to treat simple transverse fractures through axial compression and stabilization. This plate promotes primary healing by resisting rotational, bending, and shear forces, allowing for the rapid restoration of limb function. The application technique depends on the configuration of the fractures and can be used for compression, neutralization, or bridging functions (Figure 4) (Branden & Brinker, 1973; Prieur, 1983).

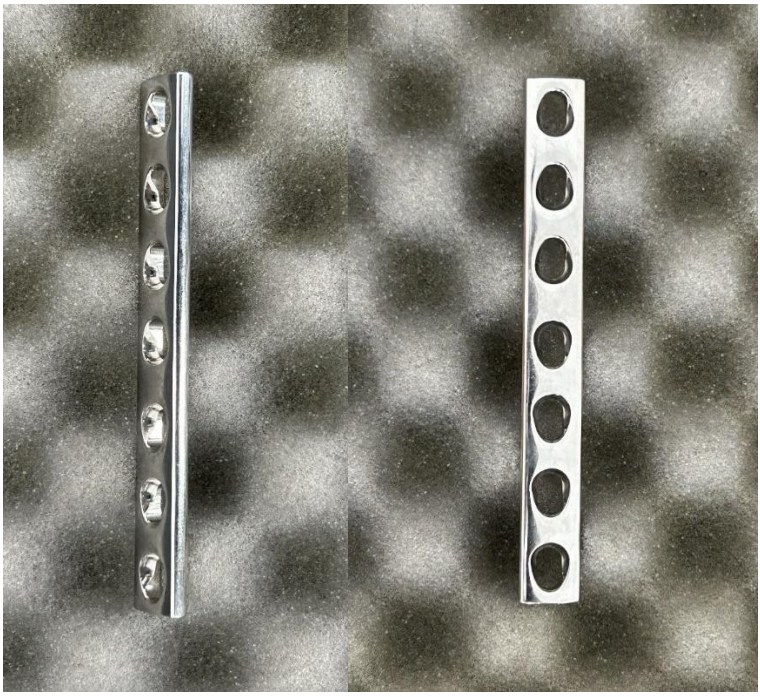

Figure 4: Veterinary DCP.

Among the fundamental bone plate systems, the most commonly used type is the dynamic compression plate (DCP). These plates are called dynamic compression plates because of the screw hole design that allows for the compression of fracture fragments. The DCP is designed to eliminate the gap between the main fracture fragments by further approximating the fracture fragment ends through screw tightening, reducing the gap to less than 0.1 mm, or in other words, creating interfragmentary compression. This makes the fragments more stable. If absolute stability is achieved, DCPs allow for primary bone healing. In addition to the oval-shaped design of the screw holes on the plate, the surface of the hole that contacts the screw head is also sloped. If the screw is placed at the elevated edge of the sloped hole, the screw head slides downward along the slope towards the lower edge of the hole as it is tightened. The fragment held by the screw moves accordingly relative to the plate, and this movement causes the fracture fragments to compress and generate compression (Tobias & Johnston, 2012; Ayyappan, 2013).

The limited contact dynamic compression plate (LC-DCP) was developed to address two issues associated with the dynamic compression plate. The underside of the plate is designed with notches and grooves to

prevent stress concentration at the screw holes. The grooved underside reduces the contact area between the bone and the plate, thus having a less negative impact on vascularization compared to a dynamic compression plate (Figure 5). The notched design also reduces the moment of inertia across the flat upper surface of the plate, thereby decreasing stress concentration at the screw holes. An additional advantage of this modification is that when bending the plate is necessary, the curve can be distributed across the entire plate rather than at the screw holes. (Boudrieau, 2011; Tobias & Johnston, 2012). The contour of the screw hole is sloped, allowing the screw head to slide on either end. As a result, when the screw is properly positioned, compression can be achieved from either end of the hole. The flexibility in application technique allows for compression on both sides of the fracture along the length of the plate, regardless of the fracture's location. In more complex fractures, particularly in treatments involving segmental fractures and cortical allografts, multiple points of compression can be achieved. In LC-DCPs, the lower side of the screw hole is wider compared to DCPs. This increased width allows screws to be placed at a greater angle both within and outside the plane of the plate (Tobias & Johnston, 2012; Ayyappan, 2013; Sateesh Kumar et al., 2019).

Figure 5: Veterinary LC-DCP.

2.2. Semitubular Plates

Semitubular plates are a standard plate type in the AO system but are not commonly used in veterinary surgery. Due to their shape, they fit well to the curved surfaces of bones. These plates are ideal for limbs where the surrounding soft tissue is limited. However, they are much weaker than a DCP of the same size, so extreme caution is advised if they are used on weight-bearing bones (Figure 6) (Tobias & Johnston, 2012).

Figure 6: Semitubular plate.

2.3. L-T Plaklar

L ve T şeklindeki plakalar, insanlarda el cerrahisi için tasarlanmıştır. Bu plakalar, küçük parçaları olan kırıklar için zaman zaman yararlı olabilir. Bu plaklar veteriner ortopedide özellikle küçük yapılı hayvanlarda distal femur, humerus, tibia ve radius kırıklarının sağaltımında kullanılmaktadır (Şekil 7) (Tobias ve Johnston 2012).

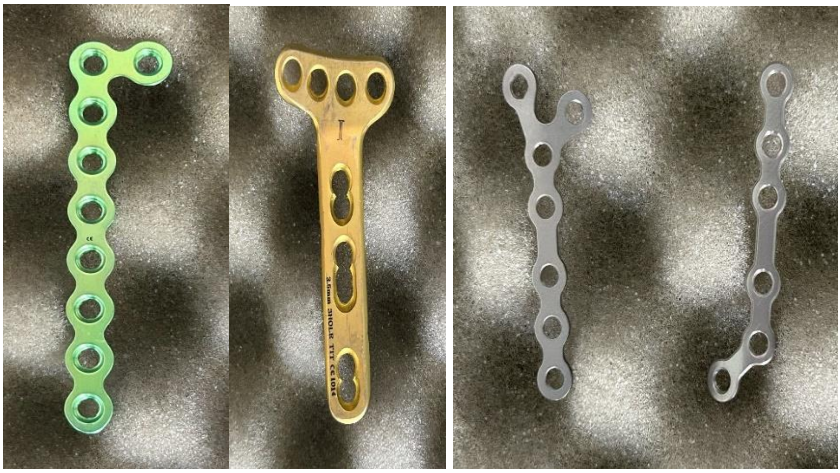

Figure7: Veterinary anatomical plates: L, T, Y, and angled L plates, respectively.

2.4. Reconstruction plates

Reconstruction plates are made of a relatively soft alloy and have V- or U-shaped notches between the screw holes (Figure 8). These notches allow the plates to be shaped in three directions, but their strength is significantly less than that of a DCP of the same size. These plates are produced in sizes of 2.0, 2.7, and 3.5 mm. Caution is advised when using them on bones subjected to high weight stress. The most important advantage of these plates is their ability to adapt to irregularly shaped and curved bones, such as the pelvis, mandible, and maxilla. In the past, they were used for distal femur fractures in chondrodystrophic breeds, as the femoral condyles are caudally inclined compared to the femoral shaft. However, their use in this region has mostly been abandoned since plates specifically designed for distal femur fractures are now available (Conzemius & Swainson, 1999; Tobias & Johnston, 2012).

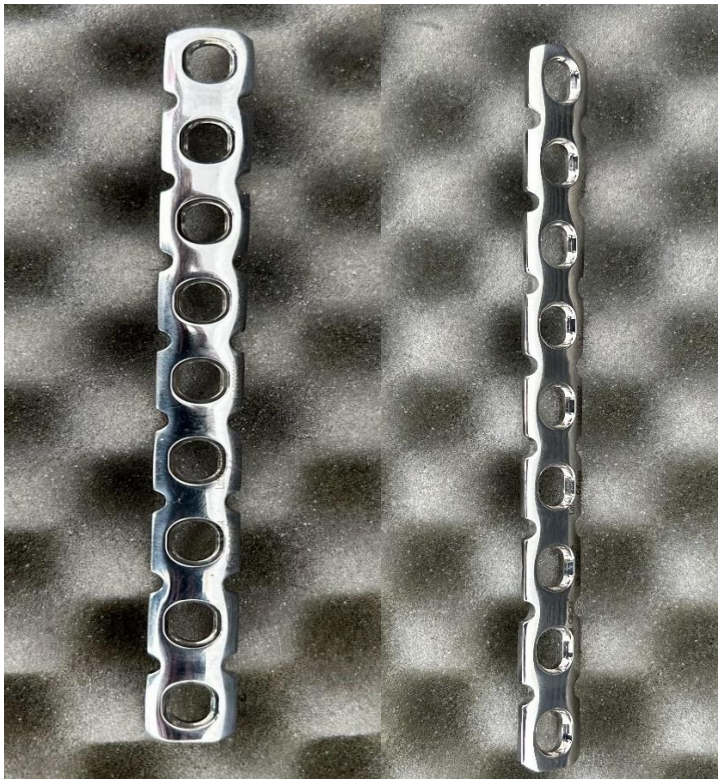

Figure 8: Reconstruction plate.

2.5. Veterinary SOP (String of Pearls) Plates

String of Pearls (SOP) plate systems are strong and flexible mechanical locking plates designed for fracture repair. They consist of a series of cylindrical sections ("internodes") and spherical components ("pearls") that allow bending medially to laterally, cranially to caudally, and twisting. These plates provide surgeons with exceptionally flexible options, especially in complex cases where stabilization across multiple planes is necessary or where the location of the fracture makes achieving full stabilization difficult. SOP plates have found extensive use in both veterinary and human medicine, with hundreds of articles published on their application. In veterinary orthopedics, SOP plates are used for fractures of the femur, humerus, tibia, antebrachium, pelvis, and spine (Ness, 2009; Field et al., 2018; Segel et al., 2018; Joshi et al., 2021; Ciou et al., 2024).

2.6. Bridged Plates

Extension plates are plates without a central hole, with holes located in the proximal and distal regions of the plate. Initially, they were designed for limb extension procedures in humans or to close the gaps left in place after the removal of diseased cortical segments. In recent years, in the treatment philosophy of comminuted fractures, bridge osteosynthesis applications have gained attention, favoring stabilization over exact anatomical reduction. As a result, extension plates are now applied directly to the bone for fracture stabilization without attempting to manipulate any fragments. Since these plates function as bridging implants, their holes are not designed to produce compression. They are available in various sizes on the market (Tobias & Johnston, 2012).

2.7. Veterinary Cuttable Plates

One of the plates developed specifically for veterinary orthopedics is the cuttable plate (VCP). These plates are longer than other standard plates and have many more screw holes, designed to be cut to the required size. The holes are not designed to produce compression and typically have a thinner profile. If a stronger and more rigid implant is needed, two cuttable plates can be placed on top of each other. These plates are produced in different sizes for 1.5 or 2.0 mm screws, and for 2.0, 2.4, or 2.7 mm screws (Figure 9) (Hammel et al., 2006; Tobias & Johnston, 2012).

Figure 9: Veterinary Cuttable Plates.

2.8. Arthrodesis Plates

Another type of plate specifically produced for veterinary applications is the T-plate, used in carpal arthrodesis surgeries for medium and large breed dogs. The neck of these plates is made wider and slightly thicker, making them stronger. They are also an ideal type of plate for distal fractures of long bones. Plates specifically designed for pancarpal arthrodesis surgeries feature holes for smaller screws at one end of the plate. This design allows the surgeon to use smaller screws in the metacarpal bones, thereby reducing the risk of iatrogenic fractures. These plates are available in sizes 2.7/2.0 and 3.5/2.7 mm on the market (Tobias & Johnston, 2012).

2.9. Acetabular Plates

Angled plates have also been produced for acetabular fractures. These plates have a design similar to DCPs. Some manufacturers produce these plates from softer materials than the steel or titanium alloys used in other plates, making them easier to shape. Acetabular plates are produced in different sizes and are selected based on the size of the patient and the configuration of the fracture (Figure 10) (Tobias & Johnston, 2012).

Figure 10: Veterinary Acetabular Angled Plate.

2.10. Special Plates for the Pelvic Region

During pelvic osteotomy procedures, specially designed and angled TPO and DPO plates are used to rotate the acetabular segment by the required amount and to maintain the stability of the ilium osteotomy until it heals.

Various variations of this design are available from different manufacturers Figure 11) (Tobias & Johnston, 2012).

Figure 11: Veterinary 25-Degree Angled Right Pelvic TPO Plate

2.11. Neutralization Plate

If the fracture is oblique, compression applied to the fracture line with a plate can cause a shearing movement between the fragments. In such cases, interfragmentary compression at the fracture line is achieved with lag screws. However, lag screws alone cannot provide sufficient resistance to the bending forces exerted on the bone under weight-bearing stress, so a plate must always be applied in addition to this reduction. Plates applied in this manner are called neutralization plates (Conzemius & Swainson, 1999; Tobias & Johnston, 2012).

2.12. Special Plates for Anterior Cruciate Ligament (ACL) Tears

In veterinary orthopedics, special surgical procedures have been developed for the treatment of anterior cruciate ligament (ACL) tears. These include CBLO (Cora Based Leveling Osteotomy), TPLO (Tibial Plateau Leveling Osteotomy), TTA (Tibial Tuberosity Advancement), and TTA-Rapid. Along with these developed techniques, plates with specific shapes, holes, and angles have been produced for each operation. The plates are named after the surgical technique for which they are specifically designed (Dymond et al., 2010; Putame et al., 2019; Arıcan et al., 2024).

2.13. Locked Compression Plates (LCP)

Locked plates and screws differ from traditional plates and screws in terms of biomechanics, design, and application. Locked implants, also known as fixed-angle implants, were developed over the past twenty years to overcome the limitations of traditional plates and screws (Figure 12). Traditional plates and screws have been widely used for decades, proving to be versatile and reliable. However, the traditional AO principles guiding their use (direct fracture exposure, anatomical reduction, and rigid fixation) require soft tissue trauma, thereby jeopardizing the biological environment at the fracture site (Filipowicz et al., 2009). Potential consequences of this approach include infection, delayed union, nonunion, and implant failures. In contrast, the philosophy of biological osteosynthesis emphasizes functional alignment, relative fracture stability, and the promotion of an optimal biological environment for fracture healing. Locked plates were designed with this philosophy in mind. Due to the fixed-angle nature of locked implants, the strength of the bone-implant construct does not rely on bone-plate contact (Perren, 2002). Therefore, locked plates eliminate the need for anatomical reduction of fracture fragments and minimize fragment movement during application. This greatly facilitates the minimally invasive application of the plate to the fracture line. Since bone-plate contact is not required, periosteal damage is minimized, preserving extramedullary vascularization (Perren, 2002; Aguila et al., 2005; Tobias & Johnston, 2012).

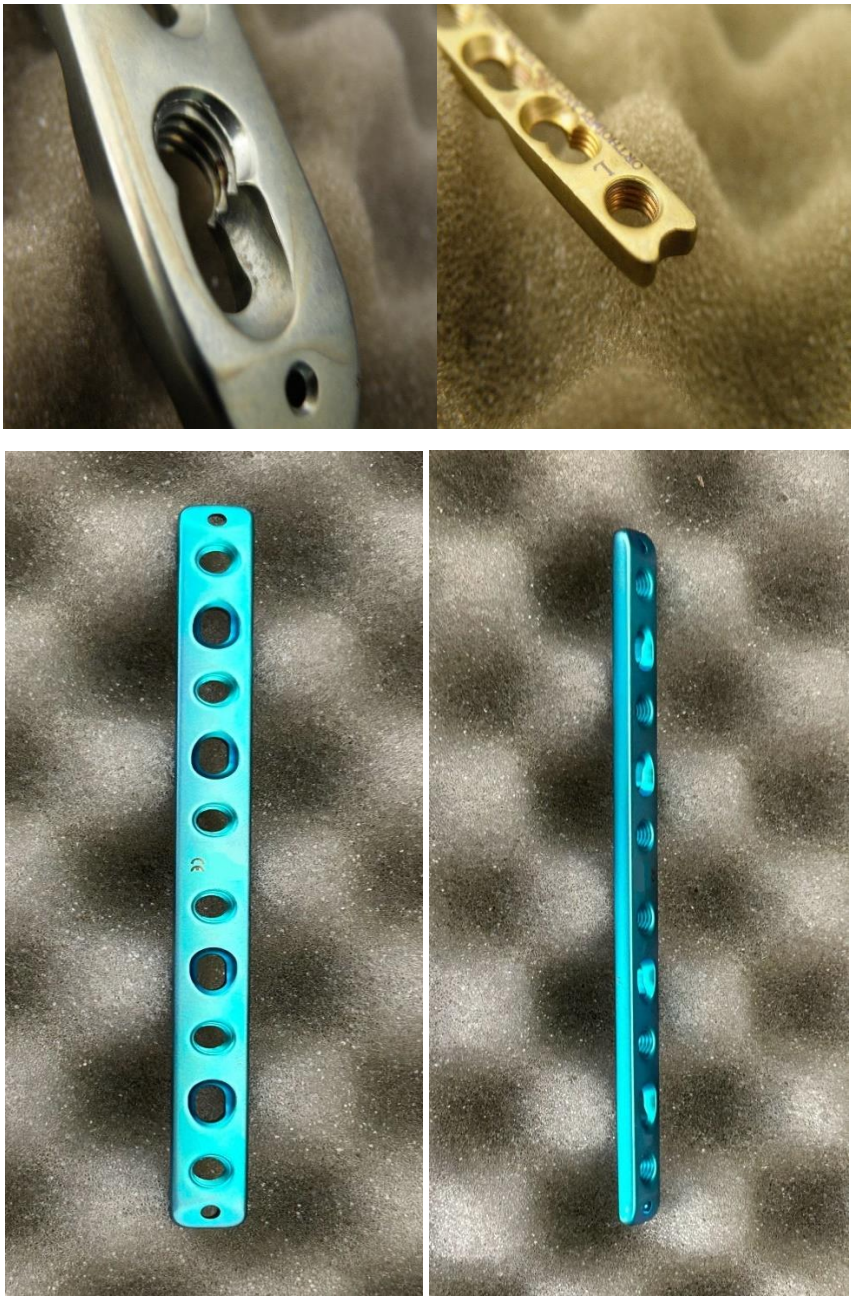

Figure 12: Veterinary Locked Compression Plates

The weak point of locked plates is the screw-plate interface. The stresses that occur over the fracture line are transferred to the screw, which has relatively weaker strength compared to the plate, and the stress accumulates significantly at the screw-plate interface. This interface can be subjected to fatigue at higher rates than either the plate or screws alone. Therefore, strengthening this interface in the design of locked plate systems can improve the longevity of the implant. This is especially critical for structures that will operate under high stress (Egol et al., 2004).

3. PLATE-ROD COMPLEX

In some complex fractures, where many of the principles of plate application are compromised, using a plate in combination with an intramedullary pin can enhance the strength of the repair system. The plate is attached to the main proximal and distal fragments. Due to the nature and structural properties of this connection, rotational and compressive forces are neutralized. However, the empty screw holes in the central portion of the plate increase the risk of failure due to bending forces on the plate. Placing an intramedullary pin into the system significantly increases the implant's resistance to bending forces. The central position and round profile of the pin provide resistance to bending in all directions (Tobias & Johnston, 2012).

In an in vitro study, 3.5 mm DCPs were used in combination with intramedullary pins that filled the medullary canal by 30%, 40%, and 50%, respectively, to cover a simulated 20 mm fracture gap. For each 10% increase in medullary canal filling, the plate stress decreased by approximately 20%. In the same study, when the medullary canal was filled to 30%, 40%, and 50%, the overall rigidity of the structure increased by 6%, 40%, and 78%, respectively. Clinically, it has been noted that pin-plate combinations that fill 50% of the medullary canal can be very rigid, which may limit the beneficial effects of micro-movements on callus formation and secondary fracture healing. Alternatively, larger diameter pins can provide greater rigidity and function as primary implants in the repair. In such cases, the plate applied to the bone can be used solely to provide resistance to rotational forces. When used this way, the space-filling effect of the pin in the medullary canal may necessitate angled placement of screws if bicortical fixation is desired, and it may even hinder the placement of bicortical screws. Provided that an adequate number of screws are applied, unicortical screws may be acceptable for this procedure, and in these cases, the application of angularly stable plates may

be appropriate for the rigidity of the fixation (Conzemius & Swainson, 1999; Hammel et al., 2006; Fulkerson et al., 2006; Fossum, 2007).

The examples provided above demonstrate the wide variety of plate designs produced for use in veterinary orthopedics, and these designs are continually increasing. Regardless of individual design differences, bone plates, when engineered and applied correctly, provide excellent stability at the fracture site. They resist tensile, compressive, and rotational forces applied to the bone. If complete anatomical reduction of the fractured bone has been achieved, the plates used also demonstrate good resistance to bending forces. However, if the bone and plate do not work mechanically together, the applied plate must withstand all the forces exerted on the limb, making it more susceptible to bending (Conzemius & Swainson, 1999; Koch, 2005; Hammel et al., 2006; Filipowicz et al., 2009).

Despite following the established principles of open reduction and conventional plate application techniques, complications such as nonunion, osteomyelitis, and sequestration continue to pose significant challenges. A retrospective study in human medicine identified several factors contributing to the emergence of these complications. Among these factors are extensive soft tissue dissection, disruption of the fracture hematoma, secondary multifocal periosteal necrosis resulting from plate compression, and iatrogenic trauma related to interfragmentary implants like lag screws and cerclage wires. The study revealed that as plate application techniques increasingly focused on achieving biological osteosynthesis, the average healing time for fractures decreased from 20 weeks to 13 weeks, while nonunion rates fell from 10% to 4% and revision surgery rates dropped from 43% to 13%. Additionally, the overall success rate of operations improved from 62% to 87%, and the utilization of bone grafts decreased significantly, from approximately 30% to 4%. These findings, along with the necessity to further diminish complication rates, have prompted a shift in the standard of care from open reduction internal fixation (ORIF) techniques to minimally invasive osteosynthesis methods in human patients. Recently, this paradigm shift has also gained traction in the field of veterinary orthopedics, bolstered by numerous studies affirming the principles of biological osteosynthesis (Hammel et al., 2006; Fulkerson et al., 2006; Tobias & Johnston, 2012).

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CHAPTER 11

AVIATION HISTORY AND ESTAŞ'S ROLE

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INTRODUCTION

Aviation is the practice or process of flying or operating aircraft. It surrounds the design, development, production, and use of all types of aircraft, including airplanes, helicopters, drones, and gliders.

The term originates from the Latin word avis, meaning "bird," reflecting the inspiration for mortal flight. Aviation can relate to both civil and military activities, as well as manned and unmanned flight. It plays a crucial role in transportation, communication, trade, defense, and disquisition.

1. HISTORY OF AVIATION

The history of aviation is a story of human imagination and determination, marked by milestones that transformed our understanding of flight and transportation. Below is an overview of its key stages:

1.1Early Experiments And Ideas

1.1.2 Old Ventures

- Early myths, such as the Greek tale of Icarus, reveal humanity's fascination with flight. However, actual flight attempts were impractical.

Balloons

- The first controlled flight was formed with hot air balloons. In 1783, the Montgolfier brothers in France launched a victorious manned balloon flight.

Figure 1.1 French aeronauts Jacques-Alexandre-César Charles and Marie-Noël Robert made the first manned ascent in a gas balloon, December 1, 1783. (URL-1)

1.1.3 19th Century Innovations

Gliders

- Pioneers like Sir George Cayley in the early 1800s studied the principles of lift and drag, developing gliders capable of carrying humans. His work laid the foundation for modern aerodynamics.
- Powered Flight Efforts: Throughout the late 1800s, inventors like Otto Lilienthal in Germany refined glider designs and The Birth of Powered Flight

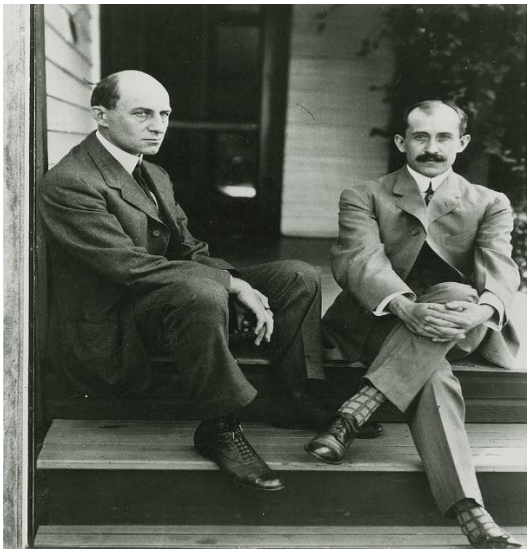

Figure 1.2. Wright brothers at their Dayton, Ohio home in 1909 (URL-2)

- Wright Brothers, On December 17, 1903, Orville and Wilbur Wright reached the first constant, controlled, and powered flight near Kitty Hawk, North Carolina. Their aircraft, the Wright Flyer, combined an engine, lightweight materials, and effective controls

1.1.4 Aviation During the World Wars

- World War I (1914-1918):

Aviation advanced rapidly, with aircraft used for reconnaissance, dogfights, and bombing missions.

Innovations included faster planes and mounted machine guns.

- World War II (1939-1945):

Aircraft became central to warfare, with the development of bombers, fighters, and transport planes like the Douglas C-47.

The introduction of jet engines revolutionized speed and performance (e.g., the German Messerschmitt Me 262)

1.1.5 Post-War Era and the Jet Age

- Commercial Aviation:

The 1950s marked the beginning of the Jet Age, with the debut of the de Havilland Comet, the first commercial jet airliner.

Airlines expanded, and aviation became accessible to the general public.

- Military Aviation:

Cold War competition fueled advancements in supersonic aircraft and stealth technology.

1.1.6 Modern and Future Aviation

- Space Exploration:

Innovations in aviation supported the development of spacecraft, enabling human exploration beyond Earth.

- Technological Innovations:

Drones, electric aircraft, and advanced navigation systems are transforming aviation.

Efforts to make aviation sustainable include the use of biofuels and electric propulsion systems.

Figure 1.3 The beginning of the first flight, December 17, 1903
Photo by John Daniels, courtesy of Library of Congress(URL-3)

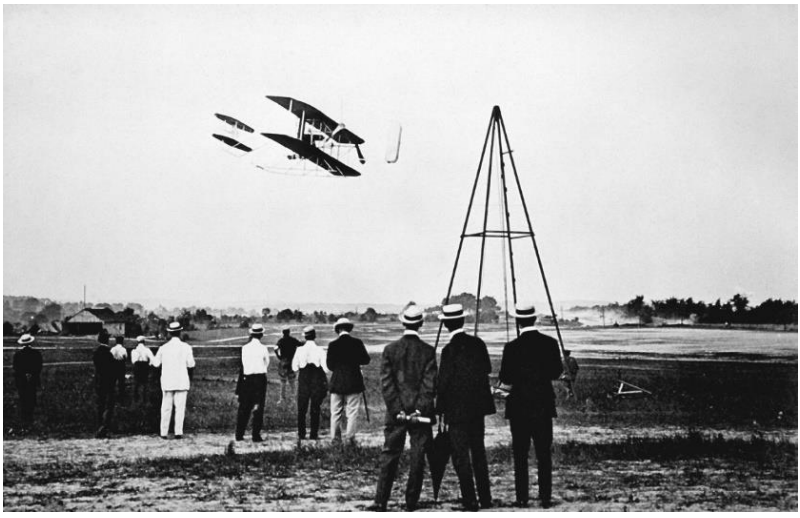

Figure 1.4. Wilbur Wright flying at Ft. Myer, Virginia. The aircraft is commonly known as the Signal Corps Flyer. July 1909. (URL-4)

2. ESTAŞ IN AVIATION INDUSTRY

Estaş is a manufacturing factory established in 1977 and it has large product scale. In 2021, it started its work on aviation and received the AS9100 certificate. In 2023, the aviation manufacturing line was established. In 2024, it started manufacturing composites by using the wet laying method. At the present time, it works and produces aviation products with various large companies. Some of these companies:

2.1 TAI (Turkish Aerospace Industries, Inc)

Estaş and TAI carries out joint projects in the field of Aerospace& Aviation. Some of these projects are:

- Manufacturing composites by using the wet lay method.

HÜRJET

Figure 2.1.Hürjet Training and Light Attack Aircraft (URL-5)

ANKA

Figure 2.2. Turkish Unmanned Aerial Vehicle (URL-6)

GÖKBEY

Figure 2.3. General Purpose Helicopter (URL-7)

ATAK

Figure 2.4. Attack Helicopter (URL-8)

2.2 BAYKAR Technologies

Baykar is a private Turkish defence company specialising in UAVs, C4I and artificial intelligence. Baykar and Estaş carries out joint projects. Some of these projects are:

BAYRAKTAR TB2

Figure 2.5. The Bayraktar TB2 is a Tactical Armed / UAV System(URL-9)

BAYRAKTAR TB3

Figure 2.6. The Bayraktar TB3 UCAV is an armed unmanned aerial vehicle system (URL-10)

2.3 BMC Power

BMC POWER was established to develop and produce the power groups required primarily in the defence sector and then in the commercial sectors where they are needed in order to meet the needs of our country. (URL-11). BMC Power and Estaş carries out joint projects. Some of these projects are:

- I4, I6, V8, V12 engine development process.
- Camshaft design and manufacturing process.

2.4 TEI (TAI AND TUSAS ENGINE INDUSTRIES)

TEI is an international manufacturer and a global design center offering high-quality products and services to aviation industry. (URL-12). TEI and Estaş carries out joint projects. Some of these projects are:

- Camshaft design and manufacturing,

TEI-PD170

Figure 2.7. Turbo Diesel Aviation Engines (URL-13)

TEI-PD222ST

Figure 2.8. Turbodiesel Aviation Engine(URL-14)

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[Captain William J. Tate, the Wrights' first host in Kitty Hawk, and family on porch of their home, the Kitty Hawk Post Office] [1900]. Glass negatives from the Papers of Wilbur and Orville Wright, Prints and Photographs Division, Library of Congress. LC-W85- 87

[Side view of glider flying as a kite near the ground, Wilbur at left and Orville at right . . . [1901]. Glass negatives from the Papers of Wilbur and Orville Wright, Prints and Photographs Division, Library of Congress. LC-W851-12

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CHAPTER 12

BIOCOMPATIBLE BIOMATERIALS IN MEDICAL APPLICATIONS

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INTRODUCTION

Definition of Biomaterials

Biomaterials are natural or synthetic materials that interact with biological systems to support or repair body functions. These materials, used in applications such as medical devices, implants, prostheses, and artificial organs, work in harmony with the body to facilitate treatment processes. The primary purpose of biomaterials is to function in compatibility with the biological systems of the body, providing safe and effective solutions. This broad category includes different classes such as metals, ceramics, polymers, and composites (Patel and Gohil., 2012, Kiradzhiyska and Mantcheva., 2019, Huang and Ding., 2021).

Historical Development of Biomaterials

Biomaterials have been used in various forms throughout history and have undergone significant evolution. Starting with simple prosthetics made from natural materials in ancient times, the use of biomaterials has transformed into advanced, high-tech materials today. The table below presents key milestones in the historical development of biomaterials:

Period	Significant Events/Discoveries	Materials Used and Applications
3000 BC	Prosthetics and artificial teeth used in Ancient Egypt	Simple prosthetics made from natural materials such as bone and seashells (Kiradzhiyska and Mantcheva., 2019).
600-1000 BC	Etruscans used animal teeth in dental prosthetics	Animal teeth were used in early dental prosthetics (Huang and Ding., 2021).
1700s	Widespread use of metals in dentistry and orthopedics	Gold and silver began to be used in prosthetics and implants (Mazaheri et all., 2021).
19th century	The first metallic implants produced with the development of modern surgery	Stainless steel and cobalt-chromium alloys were used in orthopedic implants (Teo t all., 2017).
1950s	Polymers introduced into medical implants	Polyethylene and polytetrafluoroethylene (PTFE) were used in vascular grafts and artificial organs (Mazaheri et all., 2021).

Period	Significant Events/Discoveries	Materials Used and Applications
1980s	Biodegradable polymers started to be used in medical devices	Polylactic acid (PLA) and polyglycolic acid (PGA) were used in tissue engineering and drug delivery systems (Hollinger., 1983).
2000s	Biomaterials found broader applications in tissue engineering and regenerative medicine	Hydroxyapatite and biodegradable polymers were used in bone repair and tissue regeneration (Mazaheri et all., 2021).
Present day	Nanotechnology plays a major role in the development of biomaterials	Nanocomposites and smart biomaterials are increasingly used in modern medical devices (Khalilov all., 2024).

Properties of Biomaterials

Biomaterials are known for their ability to work compatibly with biological systems, yielding successful results in medical applications. These materials influence the performance and biological compatibility of various medical devices, such as implants, prostheses, and artificial organs. Below are the key properties of biomaterials:

1. **Biocompatibility**
   One of the most important properties of biomaterials is biocompatibility. This characteristic means that the material can function in the human body without causing adverse reactions. Biocompatible materials should remain in the body for extended periods and work harmoniously with surrounding tissues. Biocompatibility is critical for long-term applications like implants and prostheses (Hollinger., 1983).

2. **Mechanical Strength**

   Biomaterials must withstand various physical forces exerted by the body. Especially in applications such as orthopedic implants, biomaterials should resist wear, tensile, and bending stresses. For example, titanium and cobalt-chromium alloys are commonly used in bone implants because they offer high strength (Teo et all., 2017, Hollingerr., 1983).

3. **Chemical Stability**

   Biomaterials used in medical devices must remain chemically stable when in contact with body fluids. Chemical stability ensures that the material maintains its functionality without corrosion or degradation over time. Metallic biomaterials should possess high corrosion resistance, while polymeric biomaterials must function without compromising their chemical structure (Teo et all., 2017, Khalilov et all., 2024).

4. **Biodegradability**

   Some biomaterials have the ability to degrade naturally over time within the body. This property is crucial for applications like temporary implants and tissue engineering. Biodegradable materials are absorbed by the body after completing their function, eliminating the need for a second surgery. Materials like polylactic acid (PLA) and polyglycolic acid (PGA) are commonly used for this purpose (Benson and He., 2024, Hollinger and Guelcher., 2012).

5. **Surface Properties**

   The surface of a biomaterial plays a major role in the biological acceptance process, as it interacts directly with body tissues. Surface roughness, chemical composition, and interaction with water can affect how cells adhere to and respond to the material. By modifying the surface of biomaterials, cell growth can be encouraged or infection risks reduced (Park and Lakes., 2007), Ratner and Bryant., 2004).

6. **Sterilization Capacity**

   Biomaterials used in medical applications must have the ability to be sterilized. The material must retain its structural integrity and biological function during sterilization processes. Metallic materials are resistant to high temperatures and can be easily sterilized, while polymeric materials may be more sensitive to high temperatures (Hollinger and Guelcher., 2012).

7. **Manufacturability and Processability**

   Biomaterials need to be easily processed and manufactured into medical devices. Polymeric materials provide wide usability due to their ability to be produced in the desired shape and size, while

metallic biomaterials are advantageous in producing high-precision implants. Cost-effectiveness and ease of processing are important considerations in the production process (Park and Lakes., 2007).

Types of Biomaterials Used in Medical Applications

Medical biomaterials are materials that interact with biological systems to provide repair, support, or functionality within the body. Different types of biomaterials are used in various medical applications for different purposes. Ceramics, metals, polymers, and composites are the main types of biomaterials, each with unique advantages, applications, and limitations.

1. Ceramics

Ceramic materials are inorganic structures with high chemical stability that are compatible with biological systems, making them important in medical applications. Ceramics are especially used in areas requiring high mechanical strength and biocompatibility. Ceramics, which are preferred in orthopedic surgery and dentistry, stand out due to their properties resembling bone and teeth. These characteristics make ceramics reliable, long-lasting solutions that do not interact with body tissues. Ceramics are widely used in implants and prosthetics due to their biocompatibility. Their ability to reduce the risk of infection after surgical procedures is a major advantage. These materials also demonstrate high resistance to wear and friction, making them suitable for long-term implant use. Ceramics are preferred in biological environments as they do not cause adverse reactions (Omidi et all., 2017, Balci and Dağdelen., 2022). One of the best-known bioceramics is hydroxyapatite (HA), which shows high compatibility with bone tissue. This material supports bone regeneration and is often used in bone grafts and orthopedic implants. Hydroxyapatite encourages bone cell growth, helping the implant naturally bond with the bone, making it an effective biomaterial in bone repair processes. Other ceramic types, such as zirconia and alumina, are recognized for their high durability and resistance to wear. Zirconia provides a natural tooth-like appearance and is used in dentistry, while alumina is preferred in applications requiring high durability, such as artificial joints and hip replacements. These materials maintain their strength and provide both aesthetic and functional solutions even in long-term use (Kiradzhiyska., Mantcheva., 2019, Huang and Ding., 2021). The main weakness of ceramics is their brittleness. Despite their high mechanical strength, they can be sensitive to sudden impacts and heavy loads. In applications under intense

physical stress, ceramics carry a risk of breaking, making them unsuitable for some uses. However, modern ceramic alloys offer innovative solutions to reduce brittleness. Ceramics do not react with body fluids and remain stable over the long term, thanks to their chemical stability. This property allows ceramics to be safely used in biological environments. In applications where implants need to remain durable for extended periods, ceramics offer high performance. Additionally, their surface properties can be adjusted to enhance cell attachment, accelerating the healing process.

In conclusion, ceramic biomaterials, due to their chemical stability and biocompatibility, have a wide range of applications in dentistry, orthopedics, and other medical fields. Ceramics like hydroxyapatite, zirconia, and alumina are ideal solutions for applications requiring high durability and longevity. Their compatibility with biological systems makes them indispensable in surgical applications.

2. Metals

Metallic biomaterials are commonly preferred in medical applications that require high mechanical strength and durability. Metals are notable for their ability to withstand the high physical stresses the body experiences. This property allows them to offer long-lasting solutions, such as orthopedic implants, dental implants, and surgical instruments. The main advantages of metallic biomaterials include resistance to corrosion and biomechanical compatibility (Balci and Dağdelen., 2022). Titanium is known for its biocompatibility and lightweight properties among metallic biomaterials. Titanium is widely used in orthopedic implants and dental applications. This metal shows excellent compatibility with bone tissue, facilitating osseointegration, which means it fuses with bone to create a stable structure. Additionally, titanium's lightweight nature minimizes the load on patients, providing comfort. Stainless steel is another widely used metallic biomaterial. It offers high durability and cost-effectiveness, making it a popular choice for surgical instruments and short-term implants. However, for long-term applications, its corrosion resistance is slightly lower than that of titanium. Nonetheless, stainless steel remains a reliable choice for short-term solutions due to its strength and durability. Cobalt-chromium alloys are known for their high hardness and wear resistance among metal biomaterials. These alloys are preferred in large orthopedic implants like hip and knee prostheses. However, they can occasionally cause allergic reactions in biological environments.

Despite this, they remain preferred for long-term implants due to their durable structure. Another important property of metals is their capacity to bear large physical loads. Metal implants, which exhibit mechanical properties similar to bone structure, are commonly used in orthopedic surgeries and artificial joints. These materials are ideal for operations that require significant structural changes and the repair of bones because they can endure the stress placed on them. The chemical stability of metallic biomaterials is another critical factor. These materials do not degrade and resist corrosion when exposed to bodily fluids. For long-term use, metallic biomaterials offer a reliable and durable solution, though different metal alloys may have varying levels of corrosion resistance, making the choice of material important for its intended use (Vallittu., 2018).

In conclusion, metallic biomaterials are widely used in orthopedic and dental applications due to their biomechanical compatibility, durability, and chemical stability. Metals like titanium, stainless steel, and cobalt-chromium alloys have become indispensable in medical applications by offering long-term biomedical solutions.

3. Polymers

Polymer biomaterials, with their flexible structures, processability, and compatibility with biological systems, have a wide range of medical applications. Both synthetic and natural polymers are widely used in medical devices, tissue engineering, and drug delivery systems. One of the most important properties of polymers is their biodegradability and biocompatibility. These properties make polymers suitable for applications like temporary implants and drug delivery systems (Teo et all., 2017). The biodegradability of polymers provides a significant advantage, particularly for temporary medical devices. Biodegradable polymers such as polylactic acid (PLA) and polyglycolic acid (PGA) break down naturally in the body after implants have served their purpose. This eliminates the need for a second surgery to remove the implant. Biodegradable polymers are also widely used in wound healing and tissue engineering (Benson and He., 2024). The flexibility of polymers allows them to be used in a variety of medical devices. Polymers can be easily produced in desired shapes and sizes, providing flexibility in the design of medical devices. Additionally, the lightweight nature of polymers ensures that implants add minimal weight to the body, increasing patient comfort. Polymers are frequently used in biomedical devices such as stents, artificial blood vessels, and sutures. Synthetic

polymers such as polyethylene (PE) and polytetrafluoroethylene (PTFE) are widely used in biomedical applications. Polyethylene is preferred in joint prostheses due to its low coefficient of friction and wear resistance, while PTFE is used in vascular grafts and circulatory systems due to its chemical stability. PTFE is also commonly used as a surgical suture material, as it maintains its structural integrity when in contact with biological fluids. Polymers also play a crucial role in controlled drug delivery systems. Polymeric drug carriers ensure that drugs reach the target area in a controlled manner, thereby increasing treatment effectiveness. Controlled release systems offer a significant advantage, particularly in targeted treatments such as cancer therapy. The use of polymers in drug delivery enhances the effectiveness and safety of treatment processes. The biocompatibility of polymers ensures their widespread use in medical applications. Both natural and synthetic polymers work in harmony with biological systems, offering reliable solutions. The surface properties of polymers can also be modified to suit biological environments, promoting cell adhesion and tissue regeneration, which in turn accelerates the healing process (Balci and Dağdelen., 2022).

In conclusion, polymer biomaterials have a wide range of medical applications due to their flexibility, biodegradability, and processability. Both synthetic and natural forms of polymers provide short- and long-term medical solutions, making them widely used in fields like tissue engineering, drug delivery, and biomedical devices.

4. Composites

Composite biomaterials are materials formed by combining two or more different materials. Composites combine the best properties of different materials, offering high mechanical strength and biological compatibility. These properties make composite biomaterials widely used in orthopedic implants, dental prostheses, and other medical devices. Composites provide long-lasting and durable solutions by working compatibly within biological environments (Vallittu., 2018). Composites often consist of a combination of polymers and ceramics or metals. Ceramic-polymer composites, which provide both rigidity and flexibility, are used in bone tissue engineering applications. While ceramics support bone tissue, polymers help the tissue regenerate naturally through their biodegradable properties. This combination optimizes the biomechanical properties, enhancing the functionality of implants (Parida et all., 2012). Composite materials work in harmony with the

body thanks to their high biocompatibility. These materials interact with biological systems to ensure the long-term success of implants. The chemical stability of composites allows implants to function in the body for extended periods without degradation. Additionally, surface modifications of composites can encourage cell attachment, speeding up the healing process. Carbon fiber-reinforced polymers are widely used in orthopedic implants and dental prostheses due to their lightweight and durable properties. These composite materials provide high strength and flexibility, ensuring that implants remain stable for long periods. Additionally, the biocompatibility of carbon fibers makes them a reliable choice for biomedical devices. Their low density helps patients feel less of the implant inside their bodies. Composite biomaterials can be made by combining biodegradable and biostable structures. Such composites are widely used in tissue engineering and regenerative medicine. Biodegradable composites dissolve naturally in the body after completing their function, without the need for additional surgical intervention. This property speeds up the healing process and reduces post-surgical complication. The high mechanical strength of composites makes them ideal for applications that require large load-bearing capacities. Metal-polymer composites are frequently used in orthopedic surgeries. These materials combine the strength of metals with the flexibility of polymers, improving the biomechanical functionality of implants. Additionally, the surface properties of composites can be adjusted to enhance biological compatibility (Desai and Shankar., 2008).

In conclusion, composite materials, combining flexibility, strength, and biological compatibility, have a wide range of medical applications. From orthopedic and dental implants to artificial joints, composite biomaterials provide long-lasting, reliable, and effective solutions. Their compatibility with biological systems makes them an indispensable part of modern medicine.

Smart Biomaterials

Smart biomaterials are defined as advanced technological materials with the capacity to respond to environmental or biological changes. These materials react to specific stimuli in their environment and use these responses to perform certain functions. Due to these features, smart biomaterials enable the development of personalized treatment methods, particularly in biomedical fields. They have significant potential in medicine as dynamic and adaptable materials that can optimize treatment processes (Anderson et all.,

2004). The most notable feature of these materials is their ability to respond to various stimuli, such as changes in temperature, pH, electrical signals, magnetic fields, or mechanical forces. Smart biomaterials are environmentally sensitive, allowing them to be used in applications like controlled drug delivery, tissue engineering, and prosthetic technologies. Their interaction with the environment is used to optimize treatments in medical applications (Amukarimi et all., 2021).Temperature-sensitive smart biomaterials can change their shape or structural properties in response to temperature fluctuations. These materials become functional when a specific temperature threshold is exceeded, providing a significant advantage, especially in controlled drug delivery. Temperature-sensitive biomaterials can deliver drugs to target tissues only when necessary, enhancing treatment efficacy and minimizing side effects (Furth et all., 2007). Another important type of smart biomaterial is pH-sensitive materials. These materials undergo chemical and physical changes depending on the pH levels in their environment. pH-sensitive biomaterials are particularly used in cancer treatments, where cancerous tissues tend to have lower pH levels. These materials activate only in low pH environments, offering targeted treatment without damaging healthy tissues (Hoffman et all., 2020). Magnetically sensitive smart biomaterials can change shape or trigger drug release when exposed to an external magnetic field. These materials contain magnetic nanoparticles, making them controllable under the influence of magnetic fields. Magnetic biomaterials offer significant advantages, especially in targeted treatments like cancer therapy. The treatment is directed to the diseased area using a magnetic field, protecting other tissues. Electroactive biomaterials respond to electrical stimuli. These materials can alter their mechanical properties or interact with biological systems under electrical signals. Electroactive biomaterials are important in nerve engineering due to their ability to interact with nerve cells. Electrical signals can encourage cell attachment and growth, making these materials useful in nerve repair and regeneration processes (Aguilar et all., 2007). Shape-memory biomaterials have the capacity to return to their original shape when an external stimulus is applied. These materials respond to stimuli like heat or mechanical stress, reverting to their previous form. Shape-memory biomaterials are widely used in orthopedic surgeries and post-trauma bone healing. In minimally invasive surgical procedures, these materials can take shape in response to body temperature, allowing implants to be placed with less intervention. Smart biomaterials hold great potential for personalized medicine. These materials can dynamically optimize treatment

processes by responding to the patient's biological and physiological conditions. For example, a smart biomaterial that triggers drug release in response to fever ensures that treatment is only activated when needed, reducing side effects and increasing treatment efficacy . In drug delivery systems, smart biomaterials enable more controlled treatments by delivering drugs to the target area at a specific time or in response to a particular stimulus. These materials are particularly beneficial in challenging processes like cancer treatment, where the targeted nature of the therapy is critical (Trucillo., 2024, Holzapfel et all., 2013, Fenton et all., 2018). Smart biomaterials ensure that drugs are activated only in diseased tissues, protecting healthy cells and enhancing treatment effectiveness. Another important application area for smart biomaterials is tissue engineering. Smart materials can interact with cells to support tissue regeneration. For instance, electrical signals can stimulate cell growth, promoting faster repair of damaged tissues. These materials offer promising solutions for tissue engineering, especially for structures like nerves and muscles that are difficult to regenerate. Biodegradable smart biomaterials dissolve naturally in the body after a certain period, eliminating the need for additional surgeries to remove implants. These materials are widely used in temporary implants and biomedical devices. Their biodegradable nature reduces post-operative complications and accelerates the healing process. Smart biomaterials provide personalized treatment options by dynamically adapting to disease progression and treatment needs. For example, a smart biomaterial that releases drugs in response to changes in blood pressure adjusts the treatment based on the patient's individual physiological conditions. These treatment methods offer a more sensitive approach to the patient's body functions, enhancing effectiveness while reducing unnecessary interventions. These materials are also used in wound healing processes. Smart biomaterials can modify treatments based on wound conditions or environmental factors. For instance, materials that release drugs based on moisture levels or change structure according to the wound healing rate can accelerate recovery and improve patient comfort. Such materials have great potential in the treatment of chronic wounds. Smart biomaterials also have broad applications in nerve repair and regenerative medicine. These materials can promote the growth of nerve cells by responding to electrical signals, speeding up the repair processes following nerve damage. Similarly, materials that support nerve regeneration can facilitate the quicker recovery of nerve functions. These

biomaterials are particularly useful in areas where nerve tissue regeneration is challenging (Perez et all., 2013).

In conclusion, smart biomaterials offer revolutionary innovations in medicine as they respond to environmental and biological stimuli. These materials, which have applications in drug delivery, tissue engineering, nerve repair, and personalized medicine, optimize treatment processes and improve patient comfort. The development of smart biomaterials is expanding the boundaries of modern medicine, enabling more effective, safe, and personalized treatment methods.

Nanobiomaterials

Nanobiomaterials are advanced technological products developed at the nanometer scale, designed to work in harmony with biological systems. These materials play a crucial role in biomedical applications. With sizes typically ranging from 1 to 100 nanometers, nanobiomaterials interact with biological processes at the cellular level, offering significant advantages in the biomedical field. Nanotechnology enhances biomaterials with new functionalities, making treatment processes more effective (Koutsopoulos., 2012). One of the most important characteristics of nanobiomaterials is their high biocompatibility and biodegradability. These materials are compatible with body tissues and minimize negative immune responses. Their small size and large surface area allow them to interact more effectively with biological environments, making nanobiomaterials suitable for applications such as drug delivery, tissue engineering, and biosensors (Hosseinkhani., 2019). Nanobiomaterials are particularly important in drug delivery systems. These materials optimize treatment by delivering drugs to target tissues. Nanoscale carriers help concentrate drugs in specific areas, reducing side effects. Nanoparticles used in cancer treatments target cancer cells, enabling treatment without harming healthy tissues. This targeted drug delivery system is a significant advantage offered by nanobiomaterials. Nanobiomaterials also play a crucial role in tissue engineering (Omidi et all., 2017, Furth et all., 2007, Aguilar et all., 2007, Perez et all., 2013). Nanofibers and nanocomposites, which interact directly with cells, are used to repair injured or damaged tissues. These materials promote cell adhesion and proliferation, forming structures similar to natural tissues. In challenging processes like bone, muscle, and nerve tissue regeneration, nanobiomaterials offer an effective solution to speed up healing. Biosensors are another important

application of nanobiomaterials. These sensors interact with biomolecules to detect diseases. Nanobiomaterials enhance the sensitivity of biosensors, enabling the early detection of conditions like cancer and diabetes. This innovation provided by nanotechnology accelerates medical diagnosis processes while increasing accuracy. More sensitive biosensors allow earlier treatment interventions, offering a significant advantage in combating diseases. Nanoparticles are the most common form of nanobiomaterials, widely used in biomedical applications. These particles bond with biological molecules, ensuring that drugs reach the correct areas in the body. Additionally, nanoparticles enable controlled drug release, enhancing the effectiveness of the treatment process. Directly transporting drugs to diseased areas helps protect healthy cells and minimizes side effects. Another prominent type of nanobiomaterial, carbon nanotubes, is widely used in various biomedical applications due to their high mechanical strength and electrical conductivity. Carbon nanotubes hold great potential in nerve engineering and tissue regeneration. These materials support the growth of nerve cells, speeding up the repair of nerve damage. They also help control biological processes by enhancing cell activity with electrical stimulation. Silver nanoparticles are widely used in biomedical applications due to their antibacterial properties. These nanoparticles interact with microorganisms, damaging their cell membranes and preventing their proliferation. Silver nanoparticles are commonly used in wound healing, surgical materials, and infection prevention applications. These materials reduce the risk of infection, particularly in surgical sutures and wound dressings, speeding up the healing process. Gold nanoparticles are also widely used in biomedical applications. Gold nanoparticles interact with biomolecules, enabling cellular-level detection and imaging. These properties make gold nanoparticles important for detecting and treating cancer cells. In cancer treatments, these nanoparticles direct drugs to tumors, increasing treatment efficacy. Nanobiomaterials are also widely used in implant technologies. Biocompatible nanomaterials help implants be better accepted by the body. These materials allow implants to work harmoniously with the body and maintain functionality for extended periods. Nanobiomaterials used in orthopedic and dental implants increase the attachment of cells to implant surfaces, strengthening the connection between tissue and implant (Hosseinkhani., 2019, Bhardwaj, and Kaushik., 2017, Shen., 2006, Miraftab., 2017, Zhao and Castranova., 2011, Pazarci et all., 2024).

Nanobiomaterials offer great promise in cancer treatments. Magnetic nanoparticles or targeted nanomaterials directly target cancer cells, optimizing the treatment process.

Applications of Biomaterials

1. Eye: Biocompatible Lenses and Eye Implants

Biomaterials play a crucial role in various applications in eye health. Contact lenses, which come into direct contact with the eye, are made from biocompatible materials. These lenses, due to their polymeric structure, offer long-lasting comfort without damaging the surface of the eye. Hydrogel and silicone hydrogel-based lenses, known for their high oxygen permeability, prevent dry eyes and enhance comfort. Their biocompatibility ensures natural use without reacting with tear fluids (Teo et al., 2017). Another common application of biomaterials in eye health is intraocular lenses used in cataract surgery. These artificial lenses are made from biocompatible materials such as silicone, acrylic, or polymethyl methacrylate (PMMA). Thanks to biomaterials, intraocular implants function for long periods without harming the biological environment of the eye. These lenses, designed to be compatible with the eye's natural structure, minimize postoperative complications and even offer protection against UV rays (Amon., 2001). Biomaterials also play a critical role in corneal transplants. Artificial corneas, made from biocompatible polymers, replace damaged or diseased corneal tissue. These materials reduce the risk of rejection and provide long-term stability. Artificial corneas maintain transparency, aiding in the restoration of vision, while maintaining stability in the eye’s fluid environment (Ghasemi-Mobarakeh et all., 2019). Another contribution of biomaterials to eye health is seen in retina implants. For patients suffering from vision loss due to retinal damage, biocompatible materials are used to create implants that mimic the retina's light-sensitive cells. Biomaterials ensure the durability of these implants without causing harm to the surrounding tissues, enabling partial restoration of vision. Materials used in retina implants generate minimal reaction in the eye, leading to successful outcomes (Lloyd et all., 2001). In summary, biomaterials have wide applications in eye health. From intraocular lenses and contact lenses to artificial corneas and retina implants, these materials provide long-term solutions compatible with eye tissues. Their ability to function without

harming the biological environment and their similarity to natural eye structures contribute to successful outcomes in eye health.

2. Heart: Cardiovascular Implants and Vascular Grafts

Biomaterials play a critical role in improving heart and vascular health. Cardiovascular implants, including heart valves, stents, and vascular grafts, are essential medical devices that rely on biocompatible materials. The biocompatibility of heart valves ensures their long-term functionality, helping the heart pump blood efficiently while minimizing immune responses (Duan et all., 2024). Materials used in heart valves and vascular grafts, such as biocompatible polymers and metal alloys, are durable and reliable. Polymer-based heart valves adapt to the heart's rhythmic movements, ensuring smooth blood flow. The surface properties of biomaterials minimize the risk of blood clotting, offering long-term durability in cardiovascular applications. This makes heart valves a reliable treatment option for patients with valve dysfunction (Çırak and Yakıncı., 2020). Vascular grafts, which replace blocked or narrowed arteries, are made from biocompatible polymers such as PTFE and polyurethane. These grafts maintain regular blood flow, treating cardiovascular diseases effectively. The flexible and durable structure of biomaterials ensures the longevity of these grafts. Additionally, their low thrombogenic properties reduce the risk of blood clotting and blockages (Hench and Thompson., 2010). Stents, another critical cardiovascular application of biomaterials, are biocompatible devices used to open narrowed arteries and regulate blood flow. Stents are typically made from metal alloys, but biodegradable polymer stents have also become more common. These stents play a vital role in preventing heart attacks and other cardiovascular diseases by maintaining the openness of arteries (Cicha et all., 2016).

In conclusion, biomaterials are essential in preserving and treating heart and vascular health. Heart valves, vascular grafts, and stents made from biomaterials offer long-term and reliable solutions for cardiovascular diseases, improving the quality of life for patients through high biocompatibility and durability.

3. Tissue Engineering: Artificial Tissue and Organ Development

Tissue engineering is one of the most advanced fields where biomaterials are used. Biomaterials act as scaffolds that support the regeneration of damaged or lost tissues. In tissue engineering, structures made

from biomaterials allow cells to attach and proliferate, promoting the formation of new tissues. These scaffolds are designed to mimic the body's natural tissue structure, providing an ideal environment for cell growth (Aguilar et all., 2007, Perez et all., 2013). Biomaterials play a significant role in bone tissue engineering. Materials such as hydroxyapatite and biodegradable polymers are used to repair bone tissue. These biomaterials support the growth of bone cells, speeding up the healing of broken bones. Additionally, these materials work in harmony with bone tissue, allowing implants to integrate with the bone. Bone scaffolds made from biomaterials are shaped to resemble the natural structure of the bone (Ong et all., 2014). Biomaterials are also essential in muscle and soft tissue regeneration. In muscle engineering, biomaterials promote the proliferation of muscle cells, helping to repair damaged muscle tissue. Scaffolds made from biodegradable polymers dissolve within the muscle tissue, supporting the natural growth process of cells. These materials facilitate the rapid healing of tissues after muscle loss or trauma (Place et all., 2009). In addition to acting as scaffolds, biomaterials also help tissues perform their functions. In artificial organ engineering, biomaterials create suitable environments for cells to grow, supporting the regeneration of organs. Structures to replace organs such as the liver, kidneys, or pancreas are developed with the help of biomaterials. This process offers potential alternatives to organ transplantation (Ahadian et all., 2017).

In summary, biomaterials have wide applications in tissue engineering and artificial organ development. Used in bone, muscle, and organ regeneration, biomaterials support the body's natural healing processes and lead to successful outcomes. These materials play a vital role in repairing damaged tissues and creating new organs.

4. Skin and Wound Healing

Biomaterials are used to accelerate the body's natural healing process in skin recovery and wound treatment. Biocompatible wound dressings create a moist environment when placed on wounds, promoting cell regeneration. These dressings are usually made from biodegradable polymers, allowing them to be naturally absorbed by the body. These materials not only speed up wound healing but also reduce the risk of infection (Ramshaw et all., 2009). Biomaterials that accelerate wound healing stimulate the regeneration of skin cells. Collagen-based biomaterials mimic the natural structure of the skin,

supporting the growth of skin cells. These materials are used to accelerate healing in conditions such as burns and severe skin injuries. Additionally, biomaterials minimize scarring and support faster skin regeneration. In the field of skin engineering, biomaterials are used to create artificial skin. Artificial skin promotes the growth of skin cells on scaffolds made from biomaterials, offering patients a natural skin appearance. These materials provide a promising treatment option for burn victims and patients who have experienced skin loss (Campoccia et all., 2013). The biocompatible structure of biomaterials allows for successful outcomes in skin engineering Biomaterials with antibacterial properties are used in wound healing to prevent infections. Biomaterials containing silver nanoparticles prevent the proliferation of microorganisms, reducing the risk of infection. These biomaterials form a protective barrier on the wound surface, speeding up healing and optimizing the wound closure process. They are also preferred in surgical procedures to prevent post-operative infections (Sorg et all., 2017, Weil., 2011).

In conclusion, biomaterials play a critical role in skin healing and wound treatment. Biocompatible wound dressings and artificial skin promote the regeneration of skin cells while reducing the risk of infection. Biomaterials used in wound treatment accelerate the healing process, allowing patients to recover more quickly.

5. Dentistry: Dental Implants and Prosthetics

Biomaterials have a wide range of applications in dentistry. Dental implants are artificial tooth roots made from biocompatible materials. Titanium and titanium alloys are the most commonly used biomaterials in dental implant production. These materials integrate with the jawbone, replacing the natural tooth root. The biocompatibility of titanium implants ensures their acceptance by the body and their long-term functionality (Balci and Dağdelen., 2022). Ceramic and zirconia-based biomaterials are frequently used in dental prosthetics and bridges. These materials are preferred for dental treatment due to their aesthetic properties, which resemble natural teeth. Zirconia offers high strength and durability, ensuring long-term use (Piconi and Maccauro., 1999). Ceramic materials, resistant to wear, also provide an aesthetic, natural appearance. These features make biomaterials crucial in dental treatments (Anusavice., 2012). Dental crowns are another important dental application of biomaterials. Crowns are designed to mimic the natural

structure of teeth, offering both aesthetic and durability through biomaterials. These crowns work in harmony with the gums, providing comfort during long-term use. Ceramic and composite biomaterials provide aesthetic and functional solutions in dental treatments (Höland., 2008). Biomaterials are also commonly used in orthodontic treatments. Braces and brackets are made from metal alloys and polymers using biomaterials. These materials ensure the proper alignment of teeth while enhancing patient comfort. Orthodontic devices made from biocompatible materials offer a safe and effective option during long-term treatment processes (Eliades and Bourauel., 2005, Bian., 2024, Suhag et all., 2024, Behera et all., 2024).

In conclusion, biomaterials are used in various dental applications such as dental implants, prosthetics, crowns, and orthodontic devices. These materials combine aesthetics and durability to offer solutions that closely resemble natural teeth. Biomaterials ensure long-term success in dental treatments, improving patient satisfaction.

CONCLUSION

Natural or artificial materials known as "biomaterials" work with biological systems to maintain or restore bodily functioning. These materials complement the body to make healing procedures easier. They are utilized in implants, prostheses, medical devices, and artificial organs. Some materials have macro, micro, and nanoscale uses in biomedicine; their use is growing rapidly each year because of their resemblance to different cell receptors, an ion or molecule that binds to metals, structural proteins, and genetic materials. These biomaterials can offer scaffolds for superior bone, tissue, and organ repair, which is necessary to preserve and prolong life.

In the field of biomaterial research, degradable materials are actively sought in areas such as bone repair and implants, and their biodegradable structures have attracted much attention because they allow avoiding a second surgery and reducing pain and costs for patients. In general, materials that can be used in bioapplication areas can be developed based on their mechanical properties, biological behaviors, biodegradation mechanisms, formability, manufacturability, costs, and ability to provide long service life in the host. The service life of biomaterials is not only affected by the properties of the materials to be selected, but also the place of use in the host and the duration of stay in that place are very important. The key factor in the use of biomaterials is biocompatibility. The production and design of new generation

biomaterials with longer life in the host will change with the selection of materials to be used.

Some of the biomaterials produced by ESTAŞ for use in medical applications are as follows:

-Titanium surfaces are used in the production of compression bolts without any coating, that is, as pure titanium.

-Titanium surfaces are coated with anodic oxidation and used in medical products such as Bone Plates and Screws, Intramedullary Nails, External Fixator Schanz Screws, Dental Superstructure Systems.

-Titanium surfaces are sandblasted and used in Aluminum Oxide or Calcium phosphate in the bodies and stems of tumor implants and dental implants.

-Stainless steel is used in bone plates and screws without any pretreatment.

Biomaterials have evolved from simple, naturally occurring compounds to complex, artificially modified molecules over a period of three decades. Due to the exponential growth in materials and technological advances since the late 18th century, future studies on this important topic should be increased and more information should be sought.

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