Use of quality tools in optimizing the production process in dental prosthesis laboratory

Uso das ferramentas da qualidade na otimização do processo produtivo em laboratório de próteses dentária

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Abstract
This article demonstrates the importance of a management and optimization project in the production processes of a dental prosthetics laboratory. It explores the use of quality tools and their contributions to the success of improvement works, enhancing product quality and production flow. All strategic points of the company were restructured by managing change projects, ensuring each directive was aimed at achieving the necessary outcomes for successful planning. Focused on a complete transformation, each department experienced changes and soon witnessed results showcased in reports, including improvements in personnel, production, finances, and strategic management. These improvements aimed to secure new contracts and expand the portfolio of clients and suppliers.

Keywords: Optimization. Layout. Restructuring. Production Flow.

Resumo
O presente artigo mostra a importância de um projeto de gerenciamento e otimização nos processos produtivos em um laboratório de próteses dentárias. O uso das ferramentas da

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Introduction

In an increasingly technological, mechanized, and automated production landscape, organizations are required to continually seek innovations related to their product, in this case, dental prostheses. Within a production segment that remains largely artisanal, such as that of dental prostheses, the challenge is greater. These are unique pieces produced in line, requiring standardization in the production flow and layout restructuring to meet the production profile's needs. Seeking strategic alternatives capable of enhancing productivity, reducing costs, ensuring higher quality and compliance, and eliminating production waste (BELLATO, MAZZONETTO, 2021).

The growing need for leaner production obliges companies to seek assistance from productive management tools that aim to coordinate the organization's flow and chain within the sector, enhancing value flow in manufacturing (SANTOS, 2019). By visiting the factory floor to comprehend the causes of waste, organizational leaders should design and implement a process that refines and directs solutions in the company's production flow (BIANCO, 2019).

The incessant need to offer products with quality and compliance, ensuring the safety of their products in the face of market competitiveness, particularly in specialized services, drives companies to seek good flow management systems and productive processes. These systems apply tools with technical standards to the company's quality system (LIMA, 2020).

Organizations, facing many difficulties in the post-World War II era, highlighted the need for changes in processes and production, which were initially oriented towards the military sector. Many companies needed to remodel themselves to adapt to the times, giving
rise to quality tools such as the Ishikawa diagram, 5W2H, PDCA cycle, among others, aimed at benefiting production gains (SOARES; DE POTÊNCIA; DE SOUSA, 2021).

Regarding the Ishikawa diagram, in 1960 Kaoru Ishikawa created the cause-and-effect diagram, also known as the fishbone diagram. Once the problems or their effects are known, this diagram allows the presentation of possible causes and reasons for their existence (SOARES; DE POTÊNCIA; DE SOUSA, 2021). In a simplified context in the industrial setting, it can be presented in six categories (the 6 Ms): Method; Machine; Measurement; Environment; Material; and Manpower. By diagnosing the cause or effect of each "M," it can be treated with more precision, thereby creating more quality and improvements within the organization.

In the circle of quality tools and improvements, also of Japanese origin, conceived by professionals in the automotive industry with the aim of aiding in planning and actions of business plan analyses, strategic planning in management-related projects. This tool responds to the following questions (What = What will be done?; Why = Why will it be done?; Where = Where will it be done?; When = When will it be done?; Who = By whom will it be done?; How = How will it be done?; How much = How much will it cost?). This tool allows versatility in organizational management (SOARES; DE POTÊNCIA; DE SOUSA, 2021).

The company's improvement process can follow the stages of PDCA, also known as the Deming Cycle (1953) and Shewhart (1986), which involves continuous improvement study, following the phases of planning (Plan), putting into practice, performing (Do), reaching the phase of checking progress, checking each process (Check), and the last stage of the cycle (Act) aims to analyze the process to identify improvement possibilities and detect objectives that were not achieved so that they can be addressed at another time (DA COSTA ALMEIDA, 2019).

The quality management in the company aims to propose a strategic plan that aims to reduce waste and prevent rework through targeted training to strengthen employees' commitment to the quality of their work. This leads the organization to have mechanisms for continuous improvement in its processes, achieving new objectives and having a prominent position in the market (SILVA; CASAGRANDE, 2022).

However, the upgrade in organizational processes fostered not only a refined production flow but also ensured financial optimization. By managing cash flow, it allowed greater autonomy in decision-making (DE ANDRADE VIEIRA, 2023). Each item presented and implemented in the company led to a scenario of improved performance, adjusting to a
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model of the globalized market which is demanding and meticulous, and there is no room for flaws.

**Materials and Methods**

The present study is the result of research conducted in a dental prosthetics manufacturing company in the city of Manaus (capital of the state of Amazonas) between 2020 and 2022. Initially, bibliographic research was carried out, along with the examination of company files and documents (photographic records, among others). Additionally, an investigation into the layout of the production process was conducted, revealing a confusing arrangement with subsequent stages located at opposite ends of the laboratory (Figure 1). The sequential production stages were identified, enabling the development of a plan to improve the current process.

![Figure 1: Current layout used in the company.](source)

The identification of the retentions causing faults, production delays, rework, damages, and the low quality of the produced pieces was possible through an important quality management tool, the Ishikawa Diagram. The diagram enabled the quality control management of dental prosthesis production in the laboratory by means of a graphical scheme identifying the six main causes of faults in the process (Method, Machine, Measurement, Environment, Manpower, Material).
Given the fact that companies have their own processes divided into groups, and these directly influence the quality of products and/or services, it is extremely important to map them to understand and seek improvements in the organization's production flow (NOVASKI; FREITAS; BILLIG, 2020). Creating a scheme with the identified points on the map allows the generation of an action plan to enhance organizational processes and improve the quality of the products manufactured in the laboratory. To understand the operation, a diagram was developed encompassing both the causes and effects of organizational problems. The first part aimed to understand the reasons for the emergence of those problems, while in the second part, the problem was structured, and possible solutions to the identified causes were presented (COSTA, 2023), as can be seen in Figure 2.

![Ishikawa Diagram](image)

**Figure 2: Graphic scheme of the Ishikawa Diagram**

Source: Authors (2023), adapted from (BELLATO, MAZZONETTO 2021).

Table 1 displays a detailed description of the most relevant stages generated by the diagram (Figure 1), derived from the stages developed in the previously used production process. This was done to identify deficiencies and, consequently, implement the necessary changes in the production process.
The applicability of the diagram allowed the identification of primary and secondary causes of the problem and their main categories, fostering dialogue among employees and ultimately recording possible causes to enhance the production process. Following the identification of these causes, an action plan was developed to improve organizational processes and the quality of products manufactured in the laboratory.

**Results**

In this section, the main results identified by the application of quality tools in the production improvement process of a Dental Prostheses laboratory located in the city of Manaus/AM will be presented.

### 3.1 Changes Implemented to Improve the Production Process

#### 3.1.1 Creation of a new Layout for Production

One of the problems identified in the Ishikawa Diagram was the unfavorable production flow within the organization, prompting us to redesign it. Using the insights generated by the diagram, highlighting the main production bottlenecks, a new layout for the company's production line was developed. This new layout depicts a more favorable production flow, with each process clearly identified, allowing for better allocation of personnel (see Figure 3).

Some issues were highlighted, and changes in the layout/process were implemented, such as: a) **Reception for production screening**, establishing an entry control for materials and other items used in production; b) **Creation of an individual service island**, where each employee performs only one step of the process at their workstation, eliminating the need to...
move around the laboratory; c) **Separate Acrylization Room**, the new location includes a counter, sink, and hydraulic system providing access to running water (with prior treatment) since it involves a process that uses high temperatures; d) **Individual room for finishing/polishing**, where the finishing touches on the pieces are done, requiring a special workstation with a sink and a motor equipped with brushes for polishing; e) **Controlled deposit with restricted access for production staff**, allowing for better inventory control.

![Figure 3: New Layout of the company.](cabinet \ balcony \ cabinet )

With the development of the new layout organizing the areas of administration and production processes, it was possible to align the stages of the company's production process, spanning administrative, financial, logistical, and production line aspects. This restructuring sought practical solutions to streamline processes, resulting in increased production agility and better visualization of quality control. It ensured comfort, safety, and efficiency while also preventing employee fatigue during the process, as each stage was designed to facilitate workflow.

### 3.1.2 Project of Modifications Based on Non-Conformities

By analyzing each company process, it was possible to implement a system for monitoring and controlling the production flow. By restructuring the production line, it was
possible to implement new techniques and better ways of handling materials, allowing the delivery of parts with guarantee and assured quality (see Table 2).

<table>
<thead>
<tr>
<th>ISHIKAWA DIAGRAM</th>
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<tbody>
<tr>
<td>Manpower</td>
</tr>
<tr>
<td>Machines</td>
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<tr>
<td>Measurement</td>
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<td>Method</td>
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<tr>
<td>Material</td>
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<tr>
<td>Environment</td>
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Table 2: Improved steps of the Ishikawa Diagram
Source: Authors (2023).

3.1.3 Implementation of the New Process in the Manufacturing of Products

In order to meet the prerequisites for improving production and services' quality, checklists were incorporated into the forms, allowing the mapping of each stage of the production flow. The created forms can be modified according to the need for activity improvement.

The diagram also allowed us to identify points that are not part of the production process, such as appointment scheduling, organization and transportation of production, reception of molded parts, storage of pieces for transportation, registration of molding specifying the recipient, and the lack of information provided by the production team regarding damaged or missing pieces, etc. Below are some changes identified through the diagram and the layout change.

3.1.4 Raw Material

During the application of the tool, the quality of the inputs used for the production of the pieces was analyzed. It was confirmed that they were of good origin and met the specifications and standards of the country's regulatory and quality control agencies, such as
Inmetro, the Ministry of Health, and the Federal Council of Chemistry. However, it was noticed that the employees were not adequately trained and often lacked familiarity with the raw material, leading to its wastage. Thus, it was proven that the material used was not the problem; therefore, the analysis shifted towards the production method.

### 3.1.5 Parts Manufacturing Process

By analyzing the process of manufacturing the pieces, it was found necessary to have quality control and monitoring during production, as the way the production process occurred did not allow for ensuring an accurate standard in the product. There were numerous stages in production, and all of them were carried out by the same technician. In other words, if there were any errors in the manufacturing process, they were only identified when the piece was delivered and tested by the customer.

In order to correct this issue, each technician was properly trained to perform only one process in the production, making them more specialized. Therefore, the error in the dental prosthesis, which was only noticed in the finished product, began to be identified during production and corrected in the subsequent stage after the error occurred. This made it possible to maintain product quality control, reduce production errors, and decrease raw material wastage.

### 3.1.6 On-site Service

With the use of the diagram, it was observed that customer (patient) service was carried out by any member of the production team who did not properly document the orders, resulting in subsequent errors in production and waste of raw materials.

The customer service was standardized through spreadsheets containing order information, and additionally, each service was subsequently supervised. A well-aligned process provides the delivery team with more security and reliability in the product. Conversely, a lack of alignment in the production flow would lead to questionable quality products.
3.1.7 Administrative

With a comprehensive project of restructuring organizational processes, the changes brought about a new vision of production and business. It redesigned and aligned processes, trained professionals, standardizing the way of production with a focus on quality and results.

An important quality tool in all restructuring processes is Brainstorming (or ideation sessions), serving as a strategic approach to communicate the company's new management policies. The changes in new equipment, new workstations, and activities were easily absorbed by the employees, which facilitated improvements.

Through the implemented restructuring, the company gained greater control over the production line, allowing for comprehensive monitoring of each sector. This enabled quicker and more precise corrections and/or anticipation of faults. Another significant aspect was the care for the materials used in work and consumption. It became easier to identify potential gaps, enabling a faster and more efficient response by reorienting the production line.

3.1.8 Economic Analysis After Implementing Improvements

After implementing and monitoring the improvement plan generated by the application of quality tools in the company, two years after implementation, the improvements can also be identified through the company's financial health. During the initial months of implementation, a positive change in the level and quality of products and services was noticed.

Figure 4 shows the quantification of production one year before the implementation of production process changes, in 2020, where 900 consultations were conducted, and 1721 pieces were manufactured, including 40% of full dentures (FD) and 60% of removable partial dentures (RPD). Despite seemingly healthy numbers, the company faced a serious problem at that time, as almost 60% of the production showed damage and/or defects, resulting in returns to the company, causing financial losses and credibility issues.

On the other hand, in 2021, after the implementation of changes, the scenario appeared more promising. There was an increase in acquiring new clients, with services expanding by approximately 50%, along with production also increasing by 50%. Meanwhile, defects and/or damages decreased to 20% compared to the previous year (2020) (Figure 4).

Analyzing the period during which the company strategically operated (2022), there was a growth of around 60% in pieces produced, clearly demonstrating the excellent outcomes
in the organization's production line (Figure 4). However, the percentage of damages and non-conformities showed a gradual decrease from 2020 to 2021 (-20%), while in 2021 to 2022, the percentage decreased even further (-2%). This is attributed to professional training, changes in workstations, and management.

Figure 4: Production Flow during the period from 2020 to 2022.
Source: Author (2023).
(patients \ complete prosthesis \ removable partial denture \ total \ losses and damage)

Upon analyzing the company's financials, the changes showed even better results. If we look at the year prior to the implementation of the new production process (in 2020), approximately 70% of the revenue was allocated to production costs, 28% to losses/damages, leaving just over 2% as cash reserves, underscoring the importance of implementing the management and governance project in the company (Figure 5). On the other hand, in the year of tool implementation, changes in the company's financial behavior were noticeable, that is, in 2021, approximately 60%, 18%, 22% were allocated to production costs, losses and/or damages, and cash reserve, respectively (Figure 5).

If we analyze the year 2022, the financial results are even better. Out of the entire revenue, only 37% was allocated to production costs. The outcomes were even better concerning losses and damages, showing that only 6% of all purchased materials were lost. This leads to an even more significant increase in current revenue of 57% (Figure 5). These results highlight the importance of developing restructuring efforts and improvements in the company's processes to achieve quality and compliance in products and balance in the organization's financial results.
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Final Considerations

This work presented a study aimed at restructuring a dental prosthesis manufacturing company located in the municipality of Manaus, Amazonas. Through tools such as 5W2H, PDCA, and the Ishikawa Diagram, processes in need of improvements were identified. These improvements were applied to the entire production and post-production process, changing the company's reality in various aspects.

The results presented show a significant increase in production percentages and an improvement in the company's treatment towards its employees, such as legal formalization, offering benefits, among others. The physical environments were redesigned to provide more agility and comfort to the professionals. Additionally, materials and equipment were incorporated to ensure greater productivity and quality assurance in the manufacture of dental prostheses.

In both periods analyzed, the company's financial performance demonstrated significant positive leaps in all aspects examined, such as increased revenue, reduced production costs, and in response to the implemented changes, a notable decrease in losses and damages was observed, allowing for greater liquidity within the organization.

The analyzed periods made the obtained results very clear, demonstrating how the planning managed to transform a previously weak culture, directed toward failure, into one characterized by high credibility, quality, and assured compliance.
References


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