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School of Management and Law
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Bachelor of Science in International Management

Bachelor Thesis

Does 3D Printing bring firms back home?
Centralization vs Decentralization

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Winterthur, 25 May 2022

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Management Summary

With the expiry of several important patents in the field of additive manufacturing in the last decade, a revolution in manufacturing in various industries was expected. The new possibilities of additive manufacturing presented new strategic challenges for management. The aim of this paper is to investigate the factors needed for Additive Manufacturing to become established in dentistry. In addition, the impact on centralised or decentralised production was investigated. The thesis focuses on the production of dental crowns. An analysis in 2012 revealed that more than one in five people in the lowest income bracket in Switzerland avoid going to the dentist because of the related costs. Therefore, the analysis should help to display solutions to solve the problem with the support of the Additive Manufacturing.

Based on a detailed review of the literature in the field of Strategic Cost Management, Quality Management, Process Management as well as Innovation Management and the semi-structured interviews a flow chart model was created. It displays the relevant factors required, that Additive Manufacturing will be implemented on a large-scale basis in dentistry in Switzerland. The primary data collection was based on five semi-structured interviews with six experts in the dentistry business. In order to obtain a meaningful research result, the entire value chain was surveyed. Thus, the different needs of dental chains, dentists and dental laboratories could be shown to simplify the implementation.

The results of the interviews showed that dentists rely on proven methods with long-term studies. It further became apparent that dentist and dental laboratories in Switzerland prefer to work with ceramics to produce dental crowns. Furthermore, it has become apparent that suppliers of 3D Printers are involved in the research and development of such materials. However, there are currently no certificates or materials that are permitted for permanent use. Another finding from the research was that the current dental tariff is a barrier to new innovations. Due to the fixed tariffs, no incentive is created to introduce new cost-effective innovations. It was also revealed that many different factors are decisive for the choice of treatment and the choice of materials for dental crowns. Due to this a complete decentralization of tooth crown manufacturing in the dental surgery seemed currently as not justifiable.

To conclude, Additive Manufacturing has many positive aspects and is suitable for the dentistry business. However, there are currently several factors which prevent a large-scale introduction of the technology. These are the printable materials as well as the biocompatibility and the clinical studies. Furthermore, there need to be an agreement with the SSO to foster the technology and to adjust the current dental tariff. If those factors together with the supportive factors mentioned in the research paper can be tackled, the large-scale implementation of Additive Manufacturing will take place. A limitation of the research study was that the customer side has not been included and further research to explore customer's expectations is suggested.

1 Introduction

In this chapter, the topic of this thesis is described, and it is briefly shown what exactly will be examined in the thesis. It further demonstrates why this research can make a significant contribution to dentistry. In the following chapter, the research question and the aim of the thesis are presented. The introduction is concluded with the limitation of the research and the structure of the dissertation.

1.1 Problem/Topic Description

Recently there has been wide interest in 3D-printing and its new production possibilities in several industries such as in the aviation, manufacturing and the medical industry (Prince, 2014). With this new technology, companies need to rethink their existing value chains. Especially in the strategic area, the question arises whether centralized production still seem to be the way forward. If one looks at rising emissions taxes, resource scarcity and the growing sustainability trend, entrepreneurs must at least reconsider their current strategic direction.

With the expiration of several important patents in the Additive Manufacturing in 2013-2015 (Bechtold, 2016), expectations of the revolution in 3D printing are increasing. The dream of producing customizable products at the same costs, was present in a wide range of management boards in several industries (Durakovic, 2018). Expectations for the new technology have been slowed down in some areas. Wagner and Walton (2016) mentioned obstacles such as strong safety regulations in the airline industry or according to Bourell et al. (2017) limited material performance in Additive Manufacturing.

This research aims to help identify the factors needed to make a transition from subtractive manufacturing to additive manufacturing in dental crowns. Further the current barriers and risks of Additive Manufacturing in dentistry are highlighted.

1.2 Significance of the Research

The costs of dental treatments was at 400 Swiss francs per capita per year in Switzerland in the year of 2008 (Imfeld, 2008). According to Imfeld (2008) 94% of the costs were paid by the patients, as the maintenance or restoration of primary and secondary oral health is based on a private contract between the dentist and the patient. A

study presented in 2017 by the Swiss Federal Office for statistics displayed that the necessity for tooth implants in Switzerland rose drastically among people over 65 from 7% in 2002 to 27% in 2012 (Kaesler, 2017).

As the Additive Manufacturing technique offers a wide range of opportunities to save costs and material not only dentists and laboratories could benefit but especially the end-customers for example low-income earners (Durakovic, 2018). A study conducted by Guessous et al. (2014) discovered in the year of 2012 that 20.6% of the lowest income group in Switzerland do not visit a dentist for economic reasons. Especially this income group was identified as high-risk for dental problems (Guessous et al., 2014). Already back then they concluded that income was highly related with forgoing dental care and that there were efforts needed to prevent high-risk population from avoiding dental care (Guessous et al., 2014).

The research could therefore not only help to facilitate the implementation of the Additive Manufacturing in dentistry but at the same time help to improve the well-being of customers, by displaying the benefits of Additive Manufacturing.

1.3 Research Objective and Research Questions

In this paper, the focus is on highlighting factors that are crucial for the implementation of Additive Manufacturing in dentistry on a large-scale basis. The aim is to show which risks must be considered as well as providing recommendations for the various contributors along the value chain. Therefore, the goal is to analyse current production procedures in the industry and analyse the benefits that Additive Manufacturing could have on them. Furthermore, the aspects of Cost Management, Quality Management, Process Management and Innovation Management are analysed in more detail, as they are identified as important strategic factors in relation to the Additive Manufacturing technology. To provide a complete picture of the existing/future value chain, 3D printing companies, dental laboratories, and dentists as well as dental chains will be examined in more detail and interviewed in semi-structured interviews.

Introduction

To centre this thesis on a specific topic and to make a relevant contribution to the research, the following research questions will be answered:

What factors are crucial that the 3D printing technology will be implemented successfully on a large-scale basis by dentists or laboratories?

What are the risks related to the strategic change to decentralized manufacturing and how should dentists evaluate them?

1.4 Limitation of the Paper

The different Additive Manufacturing techniques are not illuminated as this would lead the research in a technical direction. The dental materials for tooth crowns are only explained marginally to create a general understanding of what currently is being used in the dental industry for treating damaged teeth. It is not further questioned, which the most suitable material for dental crowns is. The present study solely focuses on the value chain in the production of dental crowns, the customer perspective is not included in this research.

1.5 Structure of the Paper

Following this introduction, the paper structure presents an overview of the relevant literature findings from available academic papers and business reports. The data from the literature review introduces first the Additive Manufacturing and its possible applications in dentistry. The literature review of Cost Management, Quality Management, Process Management and Innovation Management serves as a basis for the conducted interviews, the findings and discussion. The methodology displays the approach of the research, the applied methods as well as the instruments to acquire and analyse the primary data. The objective analysis and results of the interviews in relation to the existing literature are presented in the findings section. In the discussion section the results are interpreted, and the research questions are answered, and further recommendations are made. Finally, the conclusion summarizes the key findings, provides suggestions for future studies and reveals the limitations of the research.

2 Literature Review

In the following section, the Additive Manufacturing technology is explained and the possible applications for dentistry are shown. The aim is to display the main differences to the traditional manufacturing process, so that a basis is created for further analysis in the thesis.

2.1 Computer Aided Design in the Dentistry

Van Noort (2011) mentioned the raising importance of digital workflows in the dentistry and divided the computer aided design and manufacturing into three steps: Data acquisition, data processing and manufacturing. He further mentioned that there have been ongoing improvements in all areas. As a result, the so-called intra oral scanners facilitate the data acquisition and make it possible to create the 3D model of the denture in real time. According to Miyazaki et al. (2009) this enables the dentist to get a broader picture and to reduce the data processing time.

2.2 Additive Manufacturing

Despite the fact, that it often appears as if Additive Manufacturing is a new technology, its origins can be traced back to 1986, when Charles Hull introduced the technology (Barazanchi et al., 2017). According to the American Society for Testing and Materials (ASTM) Additive Manufacturing is “the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methods”(van Noort, 2012, p. 6). Jockusch and Özcan (2020) stated, that with Additive Manufacturing, opposed to subtractive manufacturing, there is no loss in material and the unused parts can be recycled and reused. They also pointed out the benefit of producing customized, individual products of different consistency. Roca et al.(2019) further mentioned the advantage of the fast production possibilities and therefore the reduced need of inventory. All these characteristics are perfect conditions for the dentist industry, where every customer has a different denture and needs customized tooth crowns, to prevent any discomfort or limitations in use (Rödiger et al., 2017).

Lindemann et al. (2012) stated the following advantages and disadvantages of the Additive Manufacturing technology. They have been selected according to its relevance to the dental industry.

Table 1 *Advantages and disadvantages of Additive Manufacturing*

Advantages	Disadvantages
<ul style="list-style-type: none"> • More flexible development 	<ul style="list-style-type: none"> • High investment and material cost
<ul style="list-style-type: none"> • Freedom of design and construction 	<ul style="list-style-type: none"> • Accuracy errors
<ul style="list-style-type: none"> • No production tools necessary 	<ul style="list-style-type: none"> •
<ul style="list-style-type: none"> • Less spare parts in stock 	<ul style="list-style-type: none"> •
<ul style="list-style-type: none"> • Less time to market for products 	<ul style="list-style-type: none"> •

Note. Adopted from “*Analysing Product Lifecycle Costs for a Better Understanding of Cost Drivers in Additive Manufacturing*”, by C. Lindemann, U. Jahnke, M. Moi and R. Koch, 2012, p. 179.

2.3 Damage Treatments in Dentistry

In the case a tooth was damaged there were different treatment possibilities to protect and fix the tooth. According to Christensen (2008) dentists should whenever possible practice a minimal invasive dentistry, which means to solve the problem by removing as little as possible of the tooth structure. Figure 1 highlights the different treatment methods to repair a damaged tooth. However Christensen (2008) mentioned, when placing a tooth crown, almost 1 millimetre of the tooth needs to be taken away, therefore, he recommended that dentists use whenever possible the other treatment options in the form of a filling, inlay, onlay or overlay first.

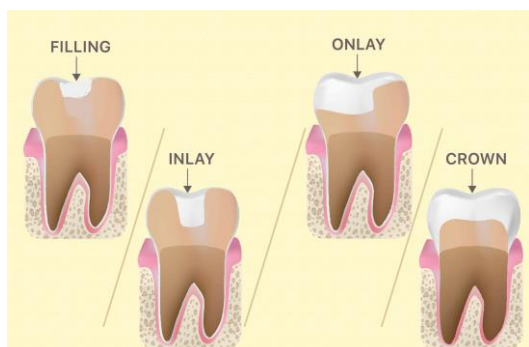


Figure 1 *Different treatments for damaged teeth*

Note. From “*Fillings vs Inlay/Onlay vs Crown*”, by Elite Dental Care, 2019

2.4 Production Concepts

Already in (2008) Beuer, Schweiger and Edelhoff outlined three different production concepts in the future dentistry. All of them will be presented in more detail below to be further analysed and compared later with the conducted interviews in the discussion.

2.4.1 Chairside Production

In this production concept according to Beuer et al. (2008) the idea was that all parts of the Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) system are established in the dental surgery. Through the chairside production dentist are getting additional independence as they are not reliant on a laboratory. Firstly, the digital oral scanner transmits the data of the patient's tooth. Together with the CAD/CAM software this enables the dentist to create the unique model of the tooth crown on the computer and send the printing order to the inhouse 3D printer. As a result, they claimed that the patient not only saves time, but it also reduces the treatment time to one single visit (Beuer et al., 2008).

2.4.2 Laboratory Production

Beuer et al. (2008) mentioned that the laboratory production concept is not differing to the traditional workflow of production, except the fact that Additive Manufacturing is being used. After the impression has been sent to the laboratory, further CAD/CAM production steps take place, and the manufactured tooth crown is compared to the master cast to check if further adjustments need to take place. To finalize the crown, "the Ceramist carries out the veneering of the frameworks in a powder layering or overpressing technique" (Beuer et al., 2008, p. 506)

2.4.3 Centralised Production

With centralised production Beuer et al. (2008) suggested that the computer aided design take place in the dental laboratory. However, the computer aided manufacturing will be outsourced to a centralised milling centre. Therefore, they argued that the outsourcing of the computer aided manufacturing requires only a smaller investment which is the digitalisation tool and the software. This results in a high qualitative production process performed by a centralised milling or printing centre with the advantage that the design for the crown still was performed by a dental technician (Beuer et al., 2008).

2.5 Strategic Cost Management

As in most managerial decisions, the cost factor is one of the important factors to base decisions on. In the following paragraphs the literature to Strategic Cost Management in relation to new production technologies is elaborated.

2.5.1 Principles of Strategic Cost Management

Shank (1989) stated that Strategic Cost Management (SCM) is based on three management models:

1. Porter's (1985) Value Chain analysis
2. Strategic Positioning Concept
3. Cost driver analysis

2.5.2 Value Chain Analysis

In his best seller "*Competitive Advantage: Creating and Sustaining Competitive Advantage*", Porter (1985) described the value chain in as a set of activities of a company, in which value is created. Therefore, he created the business model in figure 2, which displays the different primary activities and support activities. He further stated three distinctive relationships: between the activities, between business units in the firm and between the suppliers and buyers. As a result Shank (1989) stated, that it gives managers a better overview of the business structure and displays a new sight on possible cost improvement areas within the value chain as well as in its supporting structures.

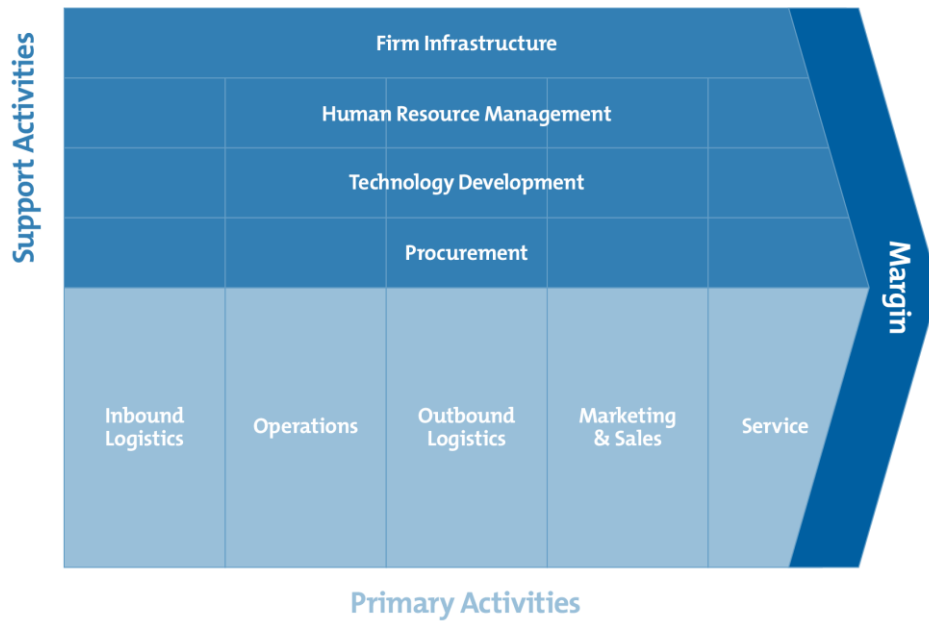


Figure 2 Porter's Value Chain Model

Note. From “*The Competitive Advantage: Creating and Sustaining Superior Performance*”, by M. Porter, 1985

It is essential that the interdependence between the primary activities but also within the support activities, is recognized and identified for proper cost management. Thompson (1967) saw this as inevitable to achieve the most efficient and effective outcomes. He further elaborated that there is a direct relationship between the intensity of interdependence and the degree of coordination required. Customized products such as tooth crowns in the dentistry, where the dentist’s input (data of customer) is required in the supplier’s process, were defined as reciprocal interdependence. As consequence an increased level of coordination as well as stronger control mechanisms are required (Thompson, 1967).

2.5.3 Strategic Positioning Concept

The Strategic Positioning Concept focuses on two major strategic cost orientations. Shank (1989) oriented himself on Porter’s (1980) strategy orientations, namely Cost Leadership or Differentiation. Porter defined them based on how a company can differentiate itself from competitors. This can be done by either offering products or services at the lowest price or by offering superior products/services, for which the customer is willing to pay a premium (M. E. Porter, 1980). Shank (1989) further stated that this decision in Strategic Cost Management is closely connected to a managers mindset and requires different relationships towards cost analysis perspectives.

Govindarajan (1986) further elaborated that a manager, who chooses a differentiation strategy, needs to be able to process information on a large scale. That is, because the differentiation can be achieved in several different areas such as: technology, design, quality but also in the marketing approach, delivery system or in the customer service. He further argued that it is crucial to focus on production and engineering functions if a low-cost strategy is applied. Govindarajan (1986) concluded that depending on the strategic positioning, the importance of strategic cost management differs heavily.

2.5.4 The Cost Driver Concept

Shank (1989) explained the Cost Driver Principle as the identification of the cost’s cause. For example, traditional management accounting defines cost as: fixed versus variable costs, average costs versus marginal costs, cost-volume profit analysis, break even analysis, flexible budget, and contribution margins. Nevertheless, he found that this gives little information about the cost “behaviour” and therefore the cost driver concept is a very important factor in SCM.

Riley (1987) divided the cost drivers in two categories, **Structural cost drivers** and **Executional cost drivers**. To illustrate he mentioned that structural cost drivers are related to the structure and organization of the firm, as well as how physical resources in form of investments are divided. Each of the following five Structural drivers shown in table 2 are related to decisions, which need to be taken by the management that affect product cost.

Table 2 *Structural Cost Drivers*

Scale	Investment size decision in manufacturing, R&D and marketing resources
Scope	Extent to Vertical Integration
Experience	How often the company has performed what it is doing
Technology	What technologies are used at each step of the value chain
Complexity	The width of products or services offered to customers

Note. From “*Competitive Cost Based Investment Strategies for Industrial Companies Manufacturing Issues*”, by D. Riley, 1987

Riley (1987) mentioned that at that time management accountants set the focus on Scale, Scope and Experience, however the factors Technology and Complexity was widely overseen. In today's world especially those two cost drivers have gained in importance. On one hand side customer demand is increasing and therefore the width of products or services is crucial. Technology on the other hand offers new possibilities to improve the cost-structure of the company, especially regarding the Additive Manufacturing in dentistry.

In table 3 the different executional drivers are shown with an explanation of each driver to facilitate the understanding. The main difference between the two types of cost drivers is that executional cost drivers can be monotonically scaled explained Riley (1987). As Shank (1989) further justified this observation with the following example: "Too much experience can be as bad as too little experience in a dynamic environment" (p.57). This leads to the conclusion that only with executional drivers more is always better (Shank, 1989).

Table 3 Executional Cost driver

Work Force Commitment	Willingness of the workforce to continuously improve (Intrapreneurship)
Total quality management	Mindset and achievement regarding product/service quality
Capacity Utilization	Scale choices on plant construction
Plant layout efficiency	Efficiency compared to current norms
Product configurations	Effective design and formulation
Exploiting linkages	Identifying opportunities in the value chain

Note. From "Competitive Cost Based Investment Strategies for Industrial Companies Manufacturing Issues", by D. Riley, 1987

2.6 Quality Management

In the 21st century with the fast-pacing technology developments, economical improvements and social wellbeing, quality standards and assurances have gained in importance (Cunningham & Hunt, 2001). In the dentistry this is seen especially, in case of an accident or when implants are needed, due to the wear of teeth, which is still a costly affair for customers (Hayashi et al., 2014).

2.6.1 Aims of Quality Management Systems

As Dahlgaard, Kristensen and Kanji (1992) stated “The aim of the quality management system is to maintain or improve the quality of a firm’s products and services, by fulfilling the satisfaction of consumer expectation” (p. 211). They further argued that there were difficulties in the evaluation of the appropriateness of such systems, due to the variation of elements in the quality systems, which are relying on the type and size of the firm. They also mentioned the invisibility of those activities because they are not explicitly categorized as quality management systems in a firm. Two categories have been classified: **preventive quality activities and inspective quality activities** (Dahlgaard et al., 1992).

In their research Dahlgaard et al.(1992) discussed the importance of preventive activities regarding the competitiveness of the company as well as the risks if management is delegating those important quality activities towards other departments. This is said to be a hopeless task in many cases as those departments do not have the capacities to implement these practices without management support. The results of these management practices were presented by Dr.-W.-Edwards-Deming (1982), who concluded that 85% of all quality failures in western companies were related to the management.

Newall and Dale (1991) took this idea further and described the importance of the integration of the employees into the quality improvement process. According to them one of the key elements is to create a shared vision of quality among all its employees no matter if it is related to either the product, the process, or the service. The development of those skills requires the understanding of one’s own work contribution in the larger context of the organization. Brache and Rummler (1988) identified four major elements

which influences employee's performance to quality improvement: the inputs given to the employee, the positive or negative consequences of an employee's input, the feedback received, and their physical mental and emotional capacity.

2.6.2 Measuring Quality Improvement

To measure and achieve quality improvement in the dentistry, Campbell and Tickle (2013) stated the necessity of quality improvement strategies, which are constantly reviewed, adjusted and optimized. They further stated the following three aspects for quality evaluation: *indicators to measure the performance, indicator scores and benchmarks* as well as *concrete aims for improvement*.

In further research Goetz et al.(2014) conducted a deeper analysis, in which they assessed the European Practice Assessment Quality Management Program. The different indicators were framed within these five key conceptual areas: *infrastructure, information, finance, quality and safety and people*. The results have shown that the intervention group outperformed the comparison group in all the above-mentioned areas. However, the most significant differences were found within "quality" and "safety and infrastructure". Goetz et al. (2014) came to the conclusion that for a successful implementation of quality management in dental care, the organizational aspects and team approach are essential. The focus can no longer be solely set on the technical aspects(Goetz et al., 2014).

2.6.3 Materials for Dental Crowns

Not only did the terms of processes and tools change a lot, but the materials used to produce dental crowns have changed as well. Lawn et al. (2004) found that ceramics have replaced the use of metals in the manufacture of dental crowns. The reason for this was improved aesthetics, superior biocompatibility and inertness (Lawn et al., 2004). However, they pointed out that one vulnerability of ceramics is their brittleness.

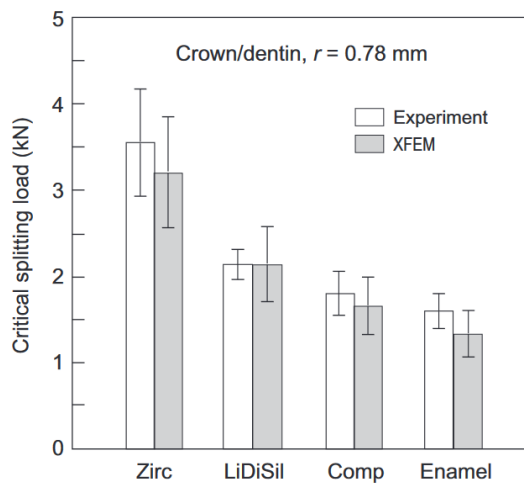


Figure 3 Predictions of critical splitting load for crowns

Note. From “Fracture-resistant monolithic dental crowns,” by Y. Zhang, Z. Mai, A. Barani, M. Bush and B. Lawn, 2016, p. 6

Further research by Zhang et al. (2016) showed increased preference of monolithic all ceramic crowns over traditional prostheses with porcelain veneers, as a consequence of reduced issues with complex fabrication, presence of residual stresses and delamination from an inner core. Their research tested three materials on its fracture endurance, namely: high translucency zirconia, machinable lithium disilicate glass-ceramic and resin-based composite with nanoparticle ceramic filler. In figure 3 the results of the experiment are displayed and Zhang et al. (2016) came to the conclusion that Zirconia is the most durable material followed by Lithium and dental composite as the weakest. However, if one compares all three materials to the natural tooth enamel, all perform better and this led to the conclusion, that all monolithic crowns can resist high bite forces.

2.7 Business Process Management

Already back in 1997 the importance of Business Process Management (BPM) was mentioned by Zairi (1997). He defined BPM as “structured approach to analyse and continually improve activities such as manufacturing, marketing, communications and other major elements of a company’s operation” p.64. BPM focuses on the main aspects of business operations, in which high leverage and big portions of value are added (Zairi, 1997).

2.7.1 Six Core Elements of BPM

Further researchers as Pritchard and Armistead (1999) confirmed this observation in the form of a survey to European Managers. The results showed that 82 percent of European Managers indicated Business Process Management as very important to the company or their business unit. They further identified three main drivers and benefits resulting from Business Process Management, which are displayed in the table 4 below.

Table 4 Drivers and benefits of Business Process Management

Main drivers	Main benefits
Need to improve responsiveness	Improved relationship with customers
Threat of Competitors	Improved cross-functional working
Need for Quality Improvement	Change in organisational culture

Note. From “*Business process management – lessons from European business*” by J. Pritchard and C. Armistead, 1999, p. 12

The drivers evolved according to Pritchard and Armistead (1999) due to fast changes in the marketplace and the need to work faster, more efficient and effective. The necessity of Business Process Management was further analysed by Rosemann and Brocke (2015) and they created a model with the six main factors which are significant for the success of BPM. These are **Strategic Alignment, People, Culture, Information Technology, Governance and Methods** (Rosemann & vom Brocke, 2015). In the following paragraphs these six factors are elaborated more in detail and are ordered according to its importance in dental industry.

2.7.1.1 Strategic Alignment

Abdolvand et al. (2008) and Pritchard and Armistead (1999) alluded the importance of aligning the Business Processes to the Corporate, Business and Functional Strategy. To guarantee an overall understanding it is important that the top management is aware of the current processes on all strategic levels. To guarantee the consistency along all strategic areas, strong linkages between business planning and performance measurement systems are a crucial element (Pritchard & Armistead, 1999). Rosemann and vom Brocke (2015) went further and said the management needs to ask itself constantly which are the core processes that should be done in-house.

2.7.1.2 People

Hung (2006) expressed the importance of people in the implementation of BPM and the strong correlation between people involvement and organizational performance. She found evidence that stronger leadership, commitment by the management and the delegation of more authority to its employees results in better performance of the organization. Social and communication skills were stated as equally important by Bergener et al. (2013) as the methodological and technical skills of employees. Also Rosemann and vom Brocke (2015) mentioned that the way in which the individuals or groups work together is essential for successful BPM.

2.7.1.3 Culture

The business culture is another crucial aspect, Crowe et al. (2002) displayed that an egalitarian culture fosters the effectiveness of BPM. The key factors of the egalitarian culture are its shared vision/information, open communication, confidence, and trust in its employees as well as making use of constructive ideas of subordinates. They further set a basis in the work environment which should have the following conditions: friendly interactions among employees, confidence and trust, close teamwork, cooperation and recognition among employees (Crowe et al., 2002).

2.7.1.4 Information Technology

According to Rosemann and vom Brocke (2015) information technology enabled new opportunities in the support of processes by different hardware, software and other information system solutions. They further stated the new opportunities of automating processes, which facilitated modelling and data analysis. Other possibilities arose around process control and measurement by dashboards which display KPI's in a facilitated overview. This results in better abilities to control, modify and improve processes in the company (Rosemann & vom Brocke, 2015).

2.7.1.5 Governance

In the context of BPM Markus and Jacobson (2015) identified Governance as clear definition of structures and rules in which decisions are taken. To this belong the responsibilities and different roles in the decision-making process, the speed of decision making and its resource allocation. For example, there must be defined standard processes, which are documented to facilitate the understanding among all employees in

the organization. Only by having a clear structure and clear roles the effectiveness of BPM can be fully achieved (Rosemann & vom Brocke, 2015).

2.7.1.6 Methods

Rosemann and vom Brocke (2015) defined Methods as “the tools and techniques that support and enable consistent activities on all levels of BPM” (p.115). This dimension focuses on specific requirements of each process lifecycle and the methods that should facilitate the development and improvement of existing processes. They concluded a close linkage between the Methods and Information Technology, due to the possibility to introduce these methods in a digitized way (Rosemann & vom Brocke, 2015).

2.8 Innovation Management Challenges

Increasing global competition, increased free trade and the advancing technological developments made Innovation Management to one of the the main topics in management discussions. To guarantee successful outcomes in global competition, Dereli (2015) raised the importance of generating new ideas, building new products, creating innovative strategies and managing them in the right way. He further made the distinction between Invention and Innovation, while Invention is related to the creation of a new idea/product or service, Innovation focuses on how to implement the new idea/product or service in the company (Dereli, 2015).

Klein and Knight (2005) analysed the challenges for companies in the implementation of new innovations and highlighted six interrelated challenges to overcome, as seen in figure 4.

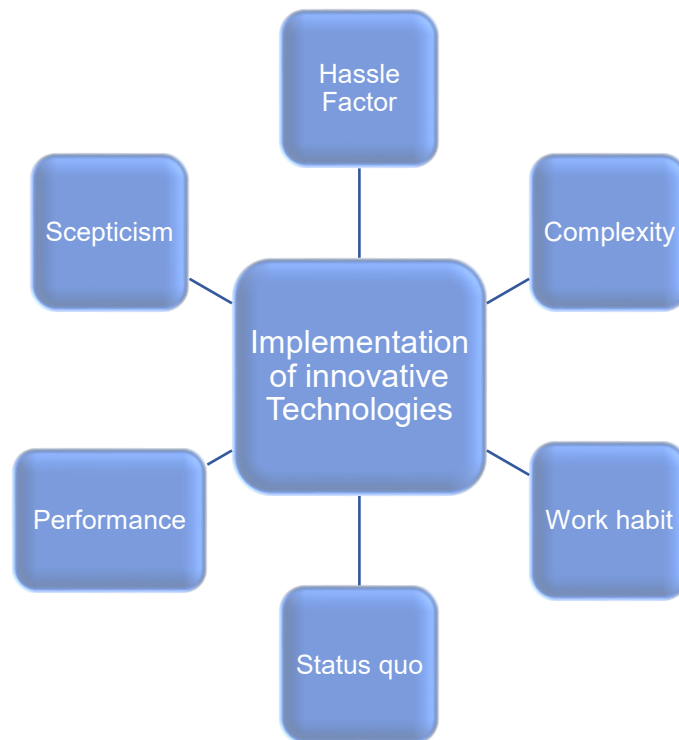


Figure 4 Challenges in the implementation of technologies

Note. Adopted from “*Innovation Implementation*” by K. Klein and A. Knight, 2005, p. 245

In regard to the **Hassle Factor**, the main difficulties mentioned were based on new technologies in terms of unreliability, quality issues, breakdowns, and design problems. This can ultimately lead to decreased employee satisfaction and create a pessimistic attitude towards innovation use (Klein & Knight, 2005).

The factor of **complexity** is according to Aiman-Smith (2002) linked to the radicalness of the introduced technology. She stated that the more complicated a new technology is to the users, the more difficult is its implementation and the user satisfaction suffers. However, she concluded that with well-planned learning activities, which support the users in their learning process, it can have a positive effect on their overall satisfaction (Aiman-Smith, 2002).

Already back in 1986 Klein and Sorra mentioned that often with new innovative technologies, the current **working habits** of certain employees and teams change

drastically. For example, this could include that an employee who worked very independently before is now supposed to collaborate in a team. Further it is possible that certain positions in the organization change and a former team leader is suddenly supposed to work in an integrated team without any superior status (Klein & Knight, 2005).

As claimed by Chung and Choi (2018) not all employees see innovation positively because they fear that it will be a threat to their job security or that it boosts performance and therefore the individual workload increases. Often those employees prefer the **status quo** and create a resisting force against the innovation. They start to criticize and raise concerns towards the innovation and it can ultimately lead to intendedly doing false reporting or implementation-targeted shirking (Chung & Choi, 2018)

Another important factor played the effect on **performance** according to Klein and Knight (2005). As they further explained that with the introduction of innovative technologies, time and effort needs to be invested for trainings, meetings, monitoring of improvement and the evaluation. This influences the performance of the employees and leads to a decrease in the short run. Reppenning and Sterman (2002) pointed out that the capability trap can be dangerous for the improvement of the implemented innovation. As there is often a trade-off between production and the improvement, as an employee often has certain predefined goals to reach, this often goes at the expense of the improvement opportunities.

Klein and Knight (2005) argued that decisions for adoption and implementation of innovation are mostly made in the top-management, without any involvement of the end-users of the new technology. Nutt (1986) conducted in an analysis among managers on how they implement innovation, 65% of them set on implementation by persuasion or edict. Without any involvement of the end-users, this can lead to general **scepticism** towards the new innovation. This especially happens because they often have great comfort in their current working habit (Klein & Knight, 2005).

2.9 Insourcing Risks

The decision to decentralize the production of tooth crowns and with that taking the decision to insource is combined with several risks. It is important to create awareness of those risks, to lay a base for dentists if they consider chairside production. Cabral, Quelin and Maia (2013) defined insourcing as “the decision to reincorporate a given activity within a company that had formerly been transferred to an external supplier”(p. 2).

According to reports by Hartman, Ogden and Hazen (2017) companies tend to refuse insourcing unless the outsourcing risk has a negative impact on the firms business objectives. They further found that when companies would decide to insource, they would look for other suppliers to maintain their current structure. For example they argued that firms see the insourcing of not core-competencies as general risk (Hartman et al., 2017).

Another aspect that was elaborated by Hartman et al. (2017) is that insourcing would require to train its employees in the required skills or even to employ additional staff. They reasoned that firms often were not willing to take this investment in labour. Especially if staff needs to be re-trained, the company has no long-term guarantee that they stay with the company (Hartman et al., 2017)

Mouritsen et al. (2022) named another risk that companies need to think about in combination with insourcing, namely the time for the implementation, that would use not only human resources but also logistic resources. As resources of companies were limited, it would come at the expense of other important services along the value chain (Mouritsen et al., 2022).

Moreover, the financial performance is another influencing factor, in the decision of insourcing and through this certain risks arose claimed by Padillo and Diaby (1999). They analysed factors such as volume flexibility, product flexibility, delivery reliability and process quality. All of those influence the insourcing decision and are combined with risks for the company's business strategy (Padillo & Diaby, 1999).

3 Methodology

This section sheds light on the methods that were applied in this research paper. The different sections present the research approach, the approach how data was collected as well as the selection of the interview partners, followed by the sampling method and finally how it was analysed. The chosen methodology is intended to answer the research question and the related sub-questions. The following chapter describes the procedure for data collection to answer the previously defined research questions.

3.1 Research Approach

This study applies an exploratory research design, as the strategic decision factors in relation to the Additive Manufacturing in dentistry has not been widely researched (Hunter & McCallum, 2019). To investigate and better understand the impact of the new manufacturing technology and its effect on the value chain in the dentistry, a qualitative research approach was applied. The common goal of qualitative research is to explore and understand a complex topic, which cannot be broken down to a few variables (Forman et al., 2008). Therefore, semi-structured interviews with experts have been performed to be able to discover relevant factors for the implementation of the technology.

3.2 Data Collection

The secondary data collection included further readings in the field of Additive Manufacturing as well as production concepts in dentistry. In a next step the focus has been on the current state of research on the topics: Strategic Cost Management, Quality Management, Business Process Management, and Innovation Management. The goal was to critically examine existing frameworks and set them in relation to the decision making of producing centralized versus decentralized. From extensive research, only a central selection is finally described. The literature research primarily explored the current state of research. Selected literature was used to choose the methodology. Since the topic is not yet heavily researched and new approaches are to be uncovered the literature review is rather brief.

The primary data was collected by qualitative interviews with experts in their respective business field. As the goal of this thesis was to identify factors which are crucial for a large-scale implementation of the Additive Manufacturing technology in the

dentistry, the qualitative approach has been identified as most suitable. As Morse (1999) stated the qualitative approach serves to create theory whereas the quantitative approach is more suitable to test theory. As the goal is to define relevant factors, the qualitative approach has been viewed as more suitable.

The questions for the semi-structured interviews were phrased based on the four main topics of Cost Management, Quality Management, Business Process Management, and Innovation Management. There were three different interview guides with slightly different questions tailored on the different aspects important to dentists, laboratories, and 3D printer suppliers. The questions were formulated in an open-ended format, to receive detailed insights from the interview partners. Due to the semi-structured organization, the interviewer had the possibility to ask follow-up questions to reach supplementing findings. The semi-structured interview enabled the interviewer to collect independent thoughts of each individual group (Adams, 2015).

The interviews were undertaken with the help of Microsoft Teams. The interviews were preferably conducted in English, at the request of the interviewees two of them were held in German. As a rule, 30 minutes to one hour was planned for the interviews, and this time frame was adhered to except for one interview which lasted almost one hour and ten minutes. With the consent of the participants, the interviews were recorded and transcribed accordingly. As agreed, the interviews conducted in German were also transcribed in German. All transcriptions can be found in the appendices D to H and were written down unchanged from what was said, except for minor corrections of repetitions.

3.3 Sampling

To create a meaningful analysis out of the qualitative research approach, a purposive sampling approach was selected. This includes the selection of well-informed experts in the research field, to guarantee a high-value adding outcome (Etikan, 2016). As the decision to centralize or decentralize involves the whole value chain interview partners of all business areas have been selected to avoid a one-sided interpretation.

As a result, the interview partners consisted of the President EMEA of Stratasys, a global 3D printer company operating in the dental industry and in several other industries. The managing director of Caddent was interviewed, a German 3D printing

centre, that supplies additive manufactured parts to the dental laboratories for further processing. The company uses the Additive Manufacturing technology already for sixteen years and has 50% of its customers in Germany and the other 50% is in France and Italy. From the laboratory side the dental lab manager of the Adent Group was selected together with the operation manager, who is at the same time a qualified dentist. To have a possibility of comparison a second dental chain in the form of the Business Developer from Swiss Smile was interviewed. To complete the qualitative Interview an independent dentist with their own dental surgery was selected.

As the research question involves the implementation of the Additive Manufacturing technology on a large-scale basis, it was seen as crucial to have a large variety among the respondents. As there are varieties among dental chains and smaller dental clinics in priorities, capabilities, and resources this selection was seen as crucial to display the different expectations and needs in their daily operating business. All interview partners have nine or more years of experience in their business function and added important value to answer the research questions.

3.4 Data Analysis

The aim of the data analysis was to discover the crucial factors for a large-scale implementation of Additive Manufacturing in dentistry. Therefore, an inductive research approach was evaluated as suitable. According to Mayring (2010) with this method the interviews are summarized in order to arrive at core conclusions. As stated by Azungah (2018) the inductive approach is based exclusively on the experiences of the participants, which fully determine the analysis. The data from the interviews has been categorized and was then compared to the theoretical framework. In a second stage the relevance of the individual categories has been identified for the implementation of the Additive Manufacturing technology to create the relevant factors from it, which was the main part of the research.

4 Findings

In the following sections, the unchanged results of the research are shown and compared objectively with the previous literature. First, the status of the usability of Additive Manufacturing in the dental industry is shown and then the topics of Cost Management, Quality Management, Process Management and Innovation Management are addressed. The results build the foundation for answering the research questions.

4.1 Additive Manufacturing in Dentistry

The results confirmed the use of Additive Manufacturing in the dental industry. However, the manufacturing process is primarily used for modelling so far. Mr. Langfeld, President from Stratasys EMEA, a company operating in the production of 3D Printing devices explained that there are two major reasons. The company has biocompatibility certifications only for certain materials for 48 hours so far. For permanent use however companies are still in development, and he added that such certifications are not easy to receive. This was confirmed by Mr Aymonier and Mr. Jaren from the Adent Group, who mentioned strong regulations in Europe. The second point is that preferred materials such as ceramics are still in their infancy in terms of development and there is also the issue of material durability and safety certification.

Nevertheless, there are already companies such as Caddent, a 3D printing centre in Germany, which prints parts of dental crowns from cobalt chrome, titanium, or precious metal alloys. These still have to be processed by a dental technician until the crown can be used by the dentist. According to Manfred Goth of Caddent, this is a firm principle of the company's philosophy. Dental technicians count as partners of Caddent and therefore it is important for the company to enable dental technicians to earn money. Mr Goth emphasised that "we do things for the dental technician with machines, which can simply be done more cost-effectively than if the dental technician does it himself in his laboratory" (M. Goth, personal communication, April 22, 2022). The company is still using subtractive Manufacturing but clearly sets the focus on Additive Manufacturing.

Not only Caddent has integrated the Additive Manufacturing in its production process, the Adent Group is using the printing technique as well. Mr. Aymonier mentioned that especially for try-ins, which the dentist uses to check if the crown is fitting

are made with 3D prints. This is due to the cheap and comparably fast production and because it will be thrown away after the try-in. He further explained that the current printable material is very opaque and therefore not yet suitable especially in the aesthetic regions of the dentition.

4.2 Positive and Negative Aspects of Additive Manufacturing

The findings from the interviews confirmed the advantages from the theory in relation to Additive Manufacturing. The new technology is particularly suitable for dentistry, where every production is unique and individual. Mr. Langfeld made the following statement.

By definition all our anatomies are unique. So especially when you look into dental applications, you have your own teeth, and they are unique. That is where you usually only need one model, but it needs to be very accurate, and it needs to give you the real patient situation in terms of surgical planning or treatment planning (A. Langfeld, personal communication, April 14, 2022).

Similar was the tenor at the Adent Group. According to Mr. Aymonier the printing for try-ins is not only very fast but at the same time cheap. But in this regard Mr. Jaren and Mr. Aymonier stated that the try-ins were printed with plastic, and they go to the trash after the dentist has checked if the crown will fit. Therefore, both said that compared to the old working method, where they used plaster, the current procedure is not very environmentally friendly, and they saw a necessity for improvement. They would wish for a material, which they could at least recycle.

Mr. Goth made a practical example to display the effect of Additive Manufacturing on the productivity compared to the traditional milling method. To produce 200 crowns with one printer, it took six to seven hours and such a printer cost roughly 400'000 Euros. For the production of the same amount, it would require ten milling machines, with a price around 100'000 Euros per machine. Therefore, he concluded that with printing it enables the company to produce many times more in quantity compared to milling.

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Another advantage was that compared to the milling there is no scrap when printing the crown. Referring to Mr. Goth who made clear that in the milling process only 80% of the material can be used, the rest is trash. With Additive Manufacturing there is no trash due to the layer-by-layer production process. Moreover, he made clear that in the milling process the machine is exposed to extreme energy and this goes at the expense of the spindle and the whole machine. Whereas the printer has an energy input of 100-200 watts and except for the slider that moves back and forwards, there are no mechanical parts. “I can also use a laser much longer than a milling machine because I need less energy to make the object” (M. Goth, personal communication, April 22, 2022).

Regarding the above-mentioned positive aspects in the view of Ms. Mang the current milling process of dental crowns in her studio is not generating a lot of scrap. According to her the computer program indicates, which size of ceramic block needs to be placed in the machine. If that was done correctly, she experienced only a small rest of ceramic in the form of waste, which was rated by her as completely acceptable.

The prices of 3D printers varied among the respondents between 50'000 and 400'000 Euros. It got clear that the disadvantage especially for smaller laboratories are the high initial investment costs. In contrast the high material costs were not mentioned by those respondents that use Additive Manufacturing.

4.3 Production Concepts

Opposed to the research of Beuer et al. (2008) the production concept of full chairside production currently seemed to be unrealistic according to several interview partners along the supply chain. For example, Mr. Frei from Swiss Smile pointed out that the staff would have to possess a certain affinity for technology and that they would also need the necessary space in each dental surgery. In addition, specialists would be needed to maintain the printers. Mr Langfeld also mentioned that if a dentist wanted to produce everything on site, he would need twice the capacity of the practice space. This is because different printers would be necessary for different materials and products. He believed that “there will always be an outsourcing element and the dental labs will have their relevance” (A. Langfeld, personal communication, April 14, 2022).

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As reported by Mr Goth another factor is that with chairside production many pre-processes and post processes would fall into the dentist's area of responsibility. Especially the effort and the initial investment in the production of metals or ceramics is often underestimated. Under these pre-processes falls the modelling on the computer with CAD programmes. Further processing steps follow when the crown comes out of the printer, such as the glazing and staining mentioned by Mr. Frei, which is performed by a dental technician. Thus, additional trained personnel would be necessary to produce chairside.

However there exist dentists that practice partial chairside production. Mr. Frei explained that they are often highly motivated to vertically integrate. According to him those dentists make almost a crown in a day. This observation was confirmed by Ms. Mang Buckman in the following statement: "So when it comes to a dental crown, in the distal area, which is more difficult to see in the molar region, it is actually the case that we always do direct crown reconstructions" (H. Mang Buckman, personal communication, May 6, 2022). Even though it was not always a complete crown but in the form of overlays or onlays was very common in her dental surgery.

On the other hand the other two production concepts described by Beuer et al. (2008) were found in the business world. Swiss Smile uses the laboratory production, to offer their dentists flexibility in options for different treatments. Mr Frei stated that the relationship between the dentist and the laboratory is very important and relies on trust. Often depending on the area in the mouth dentists have different preferences of laboratories they will choose from. He argued that everything in the aesthetic zone is very important that the crown looks perfect, therefore dentists will choose the laboratory, where they made the best experience with.

The Adent Group practices a mix between centralized production and the laboratory production. The company has a centralized laboratory, where they mill or print the parts and send it then to their smaller local laboratories for further processing. Caddent uses the centralized production concept, where they receive the plaster model, physical impressions or the data created by the intraoral scanner. After that, they print a part of the crown and send it to the laboratory for further editing. Mr. Goth further explained that their customers get great flexibility in deciding which steps of the process they want to be produced by Caddent and which they will do in the laboratory by themselves.

4.4 Cost Management

Cost management had different importance depending on the position along the Value Chain. The effect that Porter (1985) mentioned, that supporting activities like technology, in our case the 3D Printing technology, can have on the cost structure, were validated during the interview. Mr. Langfeld made the following example in the creation of tooth models “the 3D printed model per quadrant costs more than three times less in the production compared to the stone model” (A. Langfeld, personal communication, April 14, 2022). He further explained that they need to offer attractive price paradigms, so that laboratories switch from traditional methods to the additive solutions.

The direct linkage between the intensity of interdependence of suppliers and buyers and its correlated increased coordination stated by Thompson (1967) was acknowledged by all interview partners. All of them saw the close collaboration between the dentists and the laboratories as crucial, as often the exchange happens over the phone. Adent Group enables its dentists to access the screen of the dental technicians via TeamViewer to facilitate the exchange of information even further.

Several interview partners prioritized the importance of the quality of the products over its price. As determined by Mr. Aymonier the goal of the Adent Group is not to practice a low-cost strategy. They set the focus on high-quality standards and try to differentiate in the service and in the quality that is delivered. According to him good materials and well trained and highly qualified dental technicians have their price. In this regard Mr. Frei further said that dentists in Switzerland mainly care about the quality. He reasoned that the perception is often high price equals high quality and if a laboratory would come and say that they could offer the crown now for 500 Swiss francs instead of 1'500, they would be sceptical that the quality is on a comparable level.

In contrast the company Caddent has the clear goal of cost-leadership but at the same time offers highest quality, according to Mr. Goth. Currently the company is cost-leader in wide areas of the market and through constant innovation the company tries to safeguard this competitive advantage for the long-term. The fact that the company offers high quality at the same time can be seen in their customer base with 50% of its customers based in Italy and France. Mr. Goth elaborated that their advantage is the branding -

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“Made in Germany”, the reliability of delivery and consistency of quality. Even though there are several competitors in Italy and France, organized in a similar way as Caddent, and which offer significantly lower priced products, the company stays a preferred partner for dental products.

The cost driver concept by Riley (1987) also has its relevance for the interviewed companies. From the structural cost drivers Mr. Goth mentioned that by using the Additive Manufacturing technology opposed to the subtractive manufacturing, they are faster in the production, and it is cheaper. The company started to introduce Additive Manufacturing sixteen years ago and therefore has gained lots of experience over the years. Of the executional drivers he highlighted the effort, commitment, experience, and a lot of diligence that comes from the employees from which the company benefits a lot. He further explained that the employees even researched how to print precious metal and the know-how level in the Additive Manufacturing is currently on a very high level in the company.

Mr. Aymonier made a practical example to visualize the effects of full digitalized workflows on the cost structure. Through different software programmes the printing of the model gets obsolete, because the software can simulate this accurately on the computer. The price with the digitalized workflow is 240 Swiss francs instead of 340 Swiss francs. He also stated an advantage of the Adent Group from being part of European Dental Group, from where the company profits a lot of the innovation taking place in the mother company. Regarding the executional drivers the dental technicians work very closely with the dentists and each computer designed product will be sent to the dentist for validation. Because of this, mistakes or misunderstandings can be cleared immediately to guarantee a successful final product.

In contrast, these digitalization tools are closely linked to the decision of the structural cost driver regarding the investment a company wants to dedicate to production and technology. Mr. Langfeld indicated the cost of an intra-oral scanner at around 30'000 Euros, but the costs went down in recent years and the quality of the scans have improved. Also Mr. Frei commented on this topic that the newest model of scanner costs around 55'000 Swiss francs and is a large investment decision compared to impression material.

Therefore, he mentioned that this is a long-term investment as you need to take thousands of impressions until you break-even compared to the impression material.

In terms of cost structures Mr. Frei pointed out that by law the dentists are required to adopt the price from the laboratory for the crown. It is prohibited to add any mark-up and dentists can only charge for the services they provided until the crown is placed in the patient's mouth. For every service the dentists offered there is a defined number of tax points associated. Then there is a tax point value, which dentists can define by themselves. This must lay between one Swiss franc and 1.70 Swiss franc according to the Swiss dental organisation (Schweizerische Zahnärzte Gesellschaft, 2018). Mr. Frei explained that this flexibility is associated with different location costs dentists face. For example rent fees for a clinic in Zurich are higher compared to Wädenswil. The price for each service will be determined by multiplying the number of tax points of each service with the defined tax point value of the dentist.

This went in line with the interview of Ms. Mang. She confirmed that as member of the Swiss Dental association, they have fixed tariff services that they charge for the corresponding service, and they do not have a lot of flexibility. She made a practical example: "If it is a dental crown, made directly via Cerec, then that is 960 francs for the crown itself" (H. Mang Buckman, personal communication, May 6, 2022). The Cerec System was an over 50-year-old technology, invented in Zurich, where the tooth was milled out of ceramic blocks.

4.5 Quality in Dentistry

The topic of quality was very central to all respondents. The main goal is to offer patients the best possible quality. For example, Mr. Aymonier as lab manager and dental technician, said "I am here to provide quality to our patients" (P. Aymonier, personal communication, April 22, 2022). The company uses preventive quality activities for quality management along its production, which starts in the computer aided design, where they use the four-eye principle before they start to mill or print. So, the dentists can access the screen of the dental technician from their computer via TeamViewer and only after approval by the dentist the work process continues. After a product such as the crown has been milled, it will be investigated for any cracks or breakings by holding it under a special light. If there are further doubts the dental technician uses the binocular to further

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control the crown. In this regard Mr. Aymonier elucidated “if you have a good technician, you will have a good control” (P. Aymonier, personal communication, April 22, 2022).

This is in line with the statements made by Mr. Goth in relation to quality, who stated that main quality control is done by visual inspection. On the other hand, according to Mr. Goth their main quality manager is the customer. He explicated that the company cannot afford to deliver bad quality, especially in the current age of social media. He said that the company already was thinking about purchasing an X-Ray Machine to automate the control. This is ought to be a topic in the future if the company is going to grow further. Nevertheless, he assured that their current quality control runs perfectly and displayed the important role of employees in the quality assurance and improvement process.

Mr. Frei made a statement regarding the prep line when a tooth crown needs to be manufactured. Every dentist needs to define this line before he scans the mouth or makes the physical impression. There is a very high individuality among the dentists, in the way that they choose the prep-line. Due to this Mr. Frei displayed the importance of experience together with the laboratory, because the longer the collaboration exist, the faster is the seeding at the dentist’s surgery. This is due to the fact that less adjustments are necessary because the laboratory knows the preferences of the dentist.

Caddent undertakes inspective quality activities in the form of micrographs on a regularly basis. By placing components on the panel and then cutting through them. Subsequently, the micrographs are photographed under the microscope and findings are documented accordingly.

4.6 Quality Improvement in Dentistry

One aspect of quality in the dentistry starts by taking the impression of the patient’s mouth. In this regard there has been ongoing improvement related to Goetz et al.’s (2014) factor of infrastructure. Intra-oral scanners have several advantages over the traditional impression taking. As Mr. Langfeld explicated “you don’t deliver stone models anymore you deliver data” (A. Langfeld, personal communication, April 14, 2022) with that the scan of the stone model for further computer aided design gets obsolete. The scanner even captures the shade of the tooth. However, based on the statement of Mr. Frei, especially in the aesthetic region’s dentists tend to take an

additional picture with a high-quality camera to guarantee, that the shade for the new crown matches with the other teeth. He explained that on a scan it looks different than on the camera. The shade is so important that certain dentists even have the dental technician come by to determine the shade. Mr. Frei pointed out that any tiny difference in shade would be noticed by everyone immediately.

Similar services are offered for the aesthetic regions at the Adent Group by having close contact with the customer in the creation process of the crown. As specified by Mr. Aymonier they either go to the clinic or the customer can visit the laboratory and together they guarantee that the customer will be satisfied with the outcome.

4.7 Materials

During the interviews, it became clear that different views apply to the material and that it is also very dependent on the dentist. Mr. Frei outlined that this decision is often closely linked to their education. He said that “dentists are educated to use the material or procedure that has the highest clinical evidence” (F. Frei, personal communication, April 22, 2022). Therefore, dentists choose the material with which they are the most confident, which is a mix between the literature and what they have been using during their clinical experience with their patients. A younger dentist would therefore use different treatment methods and materials, than one which has been working for more than 30 years.

The extent of the required replacement is also an influencing factor. As reported by Mr. Aymonier “for a big full arch to do we won’t use the same material as for a small arch” (P. Aymonier, personal communication, April 22, 2022). For printing the models Adent Group primarily uses plastic. For milling the crown, they can use a lot of different materials but mainly EMAX or zirconia is used. This is aligned with the theory of Zhang et al. (2016) in relation to the suitability of materials for tooth crowns and the trends towards monolithic all ceramic crowns.

In relation to the material Ms. Mang explained that she uses different materials depending on the area of the mouth. For the molar area she uses zirconia and for the more aesthetic regions the EMAX material. Furthermore, she made clear that the decision of the material depends on whether the tooth has been treated before. For example, after a

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root canal treatment, the tooth appears dark, in that case she cannot use a translucent material. Otherwise, it would not look very aesthetically pleasing.

On the other hand, Caddent, which has been using the Additive Manufacturing technique for sixteen years, started by printing metals. They print cobalt chrome and titanium with the so-called laser-melting process, which is a similar process from how Caddent prints precious metals. For plastic they use stereolithographic printers as well as filament printers. This confirms the observation of Mr. Frei, that the preferences in Materials differ and thus shows that metals and precious metals are still used to produce crowns. Since January, the company has a ceramic printer and learns how to print with ceramic.

In this regard Mr. Langfeld from the 3D printing company Stratasys believed that the materials for permanent use will come, but the technologies are not there yet. This lays in the reason of material and biocompatibility certifications, but companies are in the development of possible materials. He emphasized “that’s obviously the goal that we as a supplier innovate around those materials” (A. Langfeld, personal communication, April 14, 2022). The echo is similar at the Adent Group, where Additive Manufacturing is primarily used for the try-ins for difficult cases, to double check if the computer designed crown will fit in the patient’s mouth. Mr. Aymonier expressed that in milling they know everything about it, have a lot of materials, therefore he does not see a lot of improvement possibilities in milling. On the contrary with printing, they are at the beginning, and he said that the big industry already advanced further and the Adent Group currently uses 30% of the possibilities.

4.8 BPM in Dentistry

Business process management had its relevance in the dentistry too. Several of Rosemann and vom Brocke (2015) factors were mentioned by interview partners. At Caddent the owner urged to constantly innovate in dental technology and the management had broad competences with Mr. Goth as master dental technician and business economist. His of over thirty years of experience in the dental industry confirmed the importance of top management awareness of in current processes. Another factor were the people, he said “we have very creative people in our company, they are allowed to let off steam” (M. Goth, personal communication, April 22, 2022), which displayed the trust

from the management towards the employees. This was closely linked to the business culture and according to Mr. Goth resulted in several creative ideas such as a current project, in which they developed a new automated digital process for dental prosthesis.

Similar experiences were shown by Mr. Aymonier in the context of culture and governance “it is education, communication, demonstration to prove that it work” (P. Aymonier, personal communication, April 22, 2022). He referred to the removal of the metal usage for the products at the Adent Group. Furthermore, he illustrated that this effort was combined with one year of preparation, by doing tests, thinking about implementation and how to communicate it to the employees. After the preparation was done, the Adent Group implemented the change in all clinics and laboratories in one week, without experiencing any opposition. He declared the importance of leading the way to give people confidence.

Mr. Frei stated the importance of information technology in the advancement and improvement of business processes. The laboratory work has transformed from completely manual work in the tooth crowns production process by using metal frames and wax to automated processes in the form of milling by only using manual work in the finalization of the crown. The Information technology had a massive impact on the business processes in dental laboratories. In this regard Mr. Aymonier made this statement “I think soon it will be 80% digital workflow and 20% manual work, at the moment it is 60% digital and 40% manual work” (P. Aymonier, personal communication, April 22, 2022).

4.9 Innovation challenges in dentistry

In the context of innovation, very different views towards the implementation of new technologies became apparent. There were different opinions along the value chain, but also between the same professional groups there were discrepancies towards Additive Manufacturing. Regarding the hassle factor, Mr. Frei as business developer, saw the problem that it would require printer maintenance. He expressed concerns that it would break down. Especially in the beginning because everything is new, there would occur problems. He explained, in that case the company would not use the technology for at least half a year up to a year. According to him, other specialists would tell him their

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printer were not working and that he should not bother them with this new device. He further argued that it would require staff with a high level of technological understanding.

An opposing view had Mr. Langfeld, who worked for the 3D printer company, he compared the usage similarly to a large 2D Printer in an office environment. He acknowledged that the staff need to be trained, however he said that if a non-technical guy like himself was able to use a 3D printer, the complexity would not be a problem. In addition, the employees would be trained how to replace certain consumables. Because Stratasys was aware of the high-demanding dental industry, due to this the company provided a 24hour service level for other occurring problems.

Mr. Goth from Caddent remarked in relation to the hassle factor, that the only errors that occurred were in the construction from the clients. Their experience was that the printer constructed what it was commanded that it should print. He admitted that in the beginning of the introduction of 3D printers, the support of the 3D company was at one hundred percent. However, in the large size in which Caddent was producing dental parts, the company employed industry mechanics and with that the required support went down to 20%.

Another visible factor mentioned was associated with scepticism. Mr. Frei made an example “if you would start using 3D printed crowns as of today, technology will be perfectly evolved. There would still be a lot of dentists that would want to see clinical evidence that it is lasting a certain amount of time, that it is biocompatible” (F. Frei, personal communication, April 22, 2022). Suppliers often were aware of this and published data of two to five years together with launching their product. He concluded that dentists still have the tendency to choose the older technology, because it has been out for longer and there is more clinical evidence.

4.10 Risks by insourcing tooth crown production

Mr. Frei from Swiss Smile made a statement related to a general business risk, that was not mentioned in the theory. He argued that the hygiene improved a lot among the patients and with that the necessity for tooth crowns will decrease for younger

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generations. He said that in the future it will be more about dental aesthetics such as clear aligners, which help to adjust the tooth position, for a better smile.

Another risk which was closely linked to the challenges of innovation implementations was the risk of employee satisfaction. Mr Frei noted that in the case of the implementation and if technical troubles with the printers occur, the employees would start to complain about the new method. He further made clear that they would insist to work with the old working method, because not everything was as smoothly as they are used to.

Ms. Mang saw another problem with the new technology, namely the risk of customer satisfaction. She said that the customer would need to be made aware of the new treatment method and willing to try it out. In her view, her job is to guarantee that the treatment works without any incidents. Her customers were often in a hurry and prefer that the treatment is as fast as possible, therefore she saw a risk in introducing something very new to her clients.

Mr. Langfeld saw a continued relevance in the laboratories, because according to him the dentists would need to pay additional staff, install an own little laboratory in the clinic and for all services the laboratories provide currently, it would need double the space, because of all the different printers. With this he mentioned several of the risk factors from the theory such as the human risk factor, financial risk and resource risk.

5 Discussion

This chapter first discusses the findings of the interviews together with the theory. To answer the main research question, a flow chart model was created that is intended to form the factors for the large-scale introduction of Additive Manufacturing technology in the dentistry. In addition, the second research question in relation to the risks is answered. Finally, various recommendations are made for the suppliers of the technology, the laboratories, and the dentists, which should be supportive for the introduction of Additive Manufacturing.

5.1 Advantages of Additive Manufacturing

The advantages of Additive Manufacturing have also been confirmed in practice. This is exemplified by Caddent and the Adent Group, both of which already use Additive Manufacturing in parts of their production or for modelling. The advantages of the new production technology have become apparent especially in dentistry, where every product is unique. These include faster, more efficient and more cost-effective production. In this context it is important to mention that in larger operations such as dental chains and special printing centres, the benefits are more pronounced than in the case of a small dentist. This is due to the much larger order volume. Such businesses produce around 800 to 1000 components per day in extreme cases like the German printing centre. In case of the Swiss Adent Group the volume for only crowns lays in between 10 to 50 crowns per day. With that it gets clear that the 3D printing can have a large impact on productivity and effectiveness. In terms of material consumption, additive production uses 100% of the material and no waste or scrap is generated, in contrast to subtractive manufacturing where often only 80% of the material can be used.

5.2 Centralization or Decentralization

In conjunction with centralisation or decentralisation, it has been shown that there are different production concepts which also exist in practice. It must be mentioned here that it depends very specifically on the dentist whether he produces dental crowns himself or has everything produced by the laboratory. It has been shown that, as in the example of Dr. Med. Dent Mang Buckman, dental crowns for the posterior area are produced directly in the dental surgery, but for the aesthetic area, it is preferable to work together

with a dental laboratory. It was also mentioned at Swiss Smile that certain dentists work with different dental laboratories depending on the dental area in the mouth.

Based on these findings, conclusions can be drawn that a complete decentralised production of all dental services is considered rather unlikely. Firstly, it appears that different printers would be needed for a full chairside or decentralized production. This is because for certain treatment, the teeth are still hardened with heat and different materials are being used depending on the treatment reason. Secondly a dentist does not run through all treatments frequently, so it would not pay off to buy all the different printers if they are not used regularly. A third point is that the corresponding know-how would have to be brought into the dental surgeries and this would result in higher additional costs for the dental surgeries.

From a strategic point of view a complete decentralisation is therefore not reasonable with the current state of technology. The laboratories will continue to play an important role in the dental business. Assuming that 3D printing technology continues to advance, and ceramics are printable, decentralisation of certain services could make sense if the demand from the customer side is frequently enough. Clearly, the benefits are greater for laboratories and dental chains with their own laboratories that produce crowns and other products in larger quantities for customers.

5.3 Main Factors for the Large-Scale Implementation

Even though some companies use the Additive Manufacturing technique, there is still a long way to go until it will be present on a large-scale basis. Therefore, in the following parts the necessary factors for its implementation are presented. As mainly dentists and dental chains from Switzerland have been interviewed, the presented model focuses on the dental market in Switzerland. Nevertheless, except of the part of the SSO, it can be used for achieving an international perspective. As no international dentist has been interviewed it seemed not to be adequate if the large-scale implementation would have been regarded worldwide. Nevertheless, the observations have shown that the Swiss Dental market belongs to a very safeguarded one. If the recommendations are followed the implementation in European Markets should be even faster.

5.3.1 Materials and Certificates

The interviews have shown that the materials for dental crowns are a key factor. Due to the high importance of aesthetics in dentistry, the materials play a decisive factor. But not only the aesthetics, also the strength and durability of the materials are crucial. As very high forces act on the tooth when biting, high resistance is essential. A lot has changed in the dentistry's treatment area in the past. Nowadays dentists and laboratories rely almost entirely on various ceramic materials. Especially in Switzerland this was mentioned by three different interview partners. However, the company Caddent, located in Germany, prints metal parts for further processing by dental technicians. Nevertheless, it seems unlikely that dentists who use ceramics in the subtractive process would switch back to metal parts for the dental crown only to produce with the additive technique. This can be concluded from the fact that there is now a lot of clinical evidence that ceramics are suited better in terms of biocompatibility and residual stress.

The current state of research shows that additive printing technology is not yet ready to print different ceramic materials. Currently there are only materials that can be used for 48hours but not for permanent use. To receive those certificates is very difficult in Europe and it seems that this will remain for the upcoming future. As companies need to prove with clinical evidence that the materials are biocompatible over a longer period of time and that they resist the same bite forces as the currently used materials.

At this point it needs to be mentioned that suppliers constantly are on innovating in the field, Statasys is in the process of advancing materials research with various partners. Similarly, is the drive for innovation at the printing centre Caddent which is currently testing a ceramic printer. One of the breakthroughs would be if materials as Zirkonia, EMAX as well as other ceramics that already are being used for the subtractive manufacturing could be printed. In that case the certification would be quicker, because for these materials the biocompatibility has already been proved. This would facilitate the implementation as the durability can be proven faster than the biocompatibility. If there are no ceramic printable materials the barrier for additive technology to prevail over subtractive manufacturing will stay over a longer time.

5.3.2 Dental Tariff System

Another factor and at the same time a barrier for the large-scale introduction seems to be the tariff system of the SSO in Switzerland. The fact that there are fixed tariffs for every service, and thus also for crown fabrication, means that dentists have little room for action when it comes to setting prices. The interviews have shown that the dentist orders the tooth from the laboratory, especially if it is situated in the high aesthetic area. If it is in the Molar regions, there are dentists that mill it with the Cerec System. After the tooth is created digitally, the milling machine takes 20 minutes to mill it. This can vary, depending on the ceramic material. In both situation there are different tariff positions from the SSO which the dentists overtake and charge to the customer.

Although this dental tariff serves to protect patients, it also blocks new innovations such as additive technology. This is because there is no incentive for dentists to save costs by investing in a 3D printer if they cannot take in the long-term a benefit out of it. The analysis shows that to successfully implement the technology an agreement would need to be made to foster the 3D printing technology, that from a financial point of view, laboratories or dentists can profit as well. As the technology would allow to produce at lower costs, this would enable customers to pay less for their crown. As dental crowns are expensive and start around a price level of 1'000 Swiss francs. Additive Manufacturing therefore could have a massive impact on the cost factor.

5.3.3 Training Centres

Through the interviews it became clear that dentists have a strong tendency to use methods, which established themselves through numeral studies. Especially the long-term durability and biocompatibility is crucial for the well-being of the patients and their health condition. This makes sense because dentists have an obligation to the client that the crown will last over a longer time and is biocompatible. However, this prevents the trial and use of new materials or new production possibilities. It turns out that dentists in Switzerland that are members of the Swiss Dental Association (SSO) must absolve 50 hours of continuing education each year.

This is an opportunity for suppliers to bring 3D printing closer to dentists. Especially because according to the interview's smaller dental surgeries, get less in

contact with 3D printing and have little knowledge about it. It is suggested to organise training days where the technology on site can be shown to dentists. The discussions showed that dentists generally rely on tried and tested methods. By showing them the effective advantages and removing their scepticism. It does not seem impossible to convince them of the new production methods. Only theory-based presentations seem to be less effective in convincing them. It appears to be important that the dentists or dental technicians can look at, test and try out the printed products. After all, as stated by several interview partners the handling of the materials often must be practised and confidence only comes from trying them out. These courses can be strengthened by inviting experts who already have experience with the technology and can talk about it first-hand.

5.4 Supportive Factors in the Implementation

From the interviews and theories, it became apparent that many supportive factors are considered as very important when introducing Additive Manufacturing. This is often closely linked to changing business processes which is also the case with Additive Manufacturing.

5.4.1 Vision

One supporting factor on the dentist's and laboratory's side is a clear vision, starting from the management but also including the employees. Dentists and dental laboratories need to be aware that the technology alone is not enough to make such drastic changes successful. The theory displayed that companies often already struggle with the implementation of minor changes in the business process management. This is since such changes are often decided by the management without involving the staff.

It is essential to take such decisions with the team. The idea is that by visiting training centres of 3D printing companies, the vision of Additive Manufacturing is formed or reinforced.

Once dentists realize that 3D printing can provide effective benefits, close collaboration with the laboratories must be encouraged. As the dentist is the end customer of the laboratories, he has the possibility to influence and express wishes about possible adaptations of his dental crowns or implants production.

5.4.2 Employees

The results displayed that the employees are a crucial support factor as they can generate important value for the company. Not only is their commitment important in relation to the company culture but when it comes to new technologies it is significant as well. There are big challenges when it comes to the implementation of new technologies, which dentists or laboratory managers need to overcome to guarantee a successful implementation. It is highly beneficial that employees get enough support, training, and feedback possibilities to improve the new processes and to get more efficient.

An introduction of Additive Manufacturing needs to be fully supported by all members of the company. The interview showed that in the best case this can result in long-term competitive advantages for the company itself as it is the case with the printing centre at Caddent. Their employees developed a new printing possibility of precious metals on their own and are currently writing the patent for an automated production of dental prosthesis. This displays the importance of motivated, creative employees that are willing to use new technologies and to develop them further.

On the other hand, if they need to change without any prior involvement or training the implementation can get very difficult. This is because dentists or lab managers would face the six challenges presented by Klein and Knight (2005) which would make the success of Additive Manufacturing much more difficult. In the worst case it could lead to a failure of the implementation and unsatisfied employees. Often a clear communication together with trainings, meetings and information supports and facilitates a smoothly introduction.

5.4.3 Close Collaboration and Clinical Evidence

In the dental market, where clinical studies and research are essential, close collaboration is seen as a decisive support factor. Universities have been identified as important elements to help suppliers in generating studies and even in the development of new materials for dental crowns. There often is a lot of know-how which can help to bring the technology further and they have the capabilities in the form of equipment and time to do extensive research to create clinical studies. Those must be presented at training

centres to underline the stability and durability, which the dentists or laboratory managers can visually observe with related two-to-five-year clinical evidence.

Close collaboration is not only important between the suppliers and universities but additionally between suppliers, laboratories, and the dentists. It is another aspect why training centres are seen as such an essential factor because there an open exchange among dentists, laboratories, and suppliers could take place. This can lead to a better and more customized offering and fosters the understanding of the needs and wants of the dental experts.

5.5 Flow Chart Model

As it became evident during the research and discussions with interview partners, the dental industry is not a regular business environment and therefore a flow-chart has been created as there are various barriers and linkages that become evident when it is visualized. This research pursued the following research question: *What factors are crucial that the 3D printing technology will be implemented successfully on a large-scale basis by dentists or laboratories?*

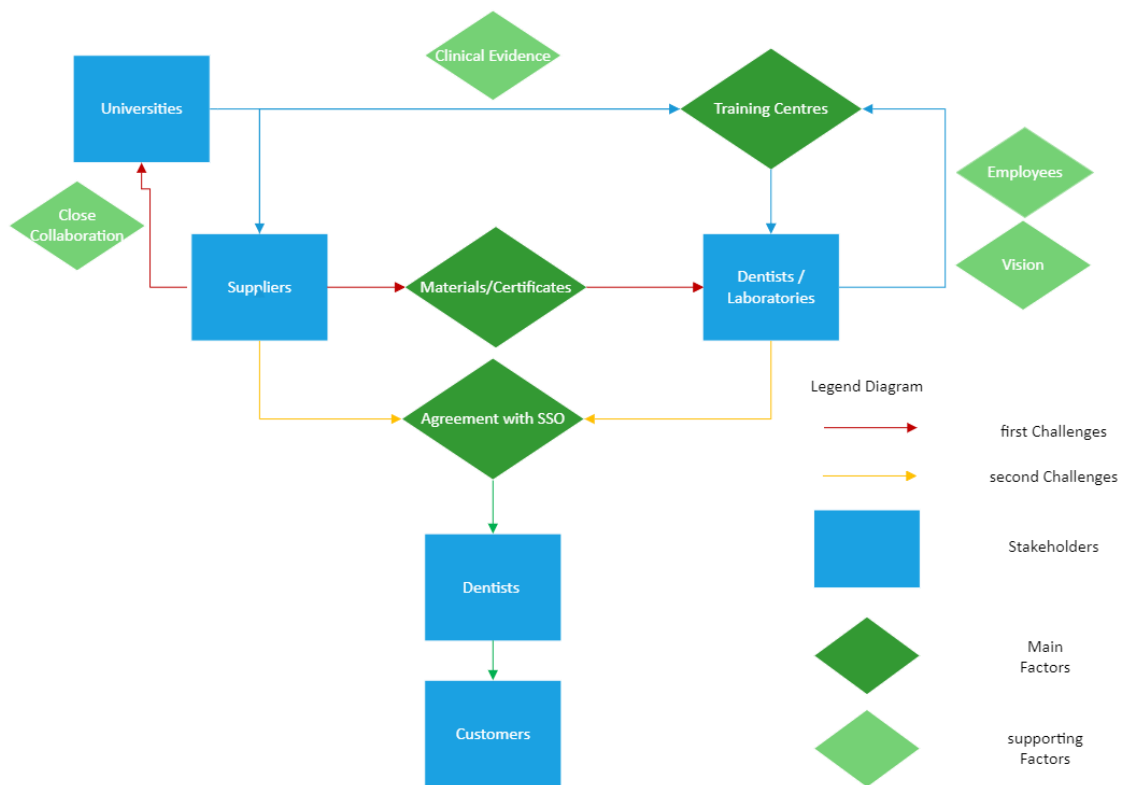


Figure 5 Flow Chart with Factors for the large-scale implementation of the Additive Manufacturing technology

As described in the upper part of the discussion and displayed in figure 4 the materials and certificates represent the first main factor which needs to be tackled by the suppliers. With that, they simultaneously foster close collaboration with universities to develop studies. This is seen as required to bring the large-scale implementation further. If those hurdles have been overcome the clinical evidence can be presented in training centres, where laboratory managers and dentists can learn and try out the developed materials and support in improving them further.

After a substantial number of dentists and laboratories realize the potential and benefits of Additive Manufacturing, they should initiate a request together to integrate and foster the new technology in the dental taxation system. At the same time suppliers should use their experience in the international 3D printing to increase the pressure on the SSO. Only after an agreement is made, dentists can start to offering 3D printing next to the traditional method to their customers.

It is generally regarded that there would be customers that are willing to try out the crowns out of the 3D printer. As customers currently often do not have any choice to choose their treatment method, the status quo comes at the cost of the customers. With 3D printing they would have the possibility to get a significantly cheaper tooth crown. Especially in the dental sector prices for crowns are quite high and therefore economically less fortunate people or younger technologically verse people could be a target group. It is clearly that in the beginning customers would need to get a confirmation that in the case there appear complications, that they could switch to the traditional method.

5.6 Risks

In connection with the topic of centralisation and decentralisation, this thesis has dealt with possible risks of decentralisation. The following sub-question was posed at the beginning of this research: *What are the risks related to the strategic change to decentralized manufacturing and how should dentists or laboratories evaluate them?*

During the research, it became clear that decentralised production would simultaneously result in insourcing. This is since dentists in Switzerland either work with local laboratories or produce their dental crowns chairside. However, there are many different practices. Not only was it difficult to find appropriate theories on the risks of

insourcing, but it also became apparent that due to the current state of technology, many dentists have not dealt with a potential insourcing of dental crowns. The assessments are therefore based on individual statements from the interviews and on the researcher's evaluation.

In this context, it is important to mention that as long as one 3D printer cannot print different materials in different procedures, an adaption leads to various risks. There are still process steps that need to be made by a dental technician, especially in the high aesthetic area. As of this, the dentist would need to employ additional employees or would have to invest in training for existing personnel. He furthermore would need to invest in different printers, which also leads to an increase in demand of space. Linked to that, he would need to have enough demand for the different treatments. All this leads to a lot of risks that would come with such a decision.

The risk of uncertainty with the technology, employees and service requests are identified as too high. It is shown that a complete decentralization for most dentists would not make sense. The risks overweight the potential benefit and from a financial point of view this would not be profitable with the current technological possibilities. It needs to be mentioned if one printer could print all different products and materials, without any dental technician work needed, then the risks would need to be re-evaluated.

In the case of laboratories in relation with dental chains, the business model of the Adent Group is viewed as very effective. Adent owns a main laboratory, where they positioned all their milling machines and 3D printers for the creation of models, as well as smaller labs in different locations for the further processing of the dental products. With that they do not have the risk of unused capacities like it would be the case if a dentist decentralizes the whole manufacturing. Laboratories supply a lot of different customers and therefore a centralized approach is still the most logical to apply. It needs to be concluded that due to the current technical barriers the risks could not be drawn from the interviews. The technology is not so far though as dentists would take them into consideration. Namely the materials and certificates are not usable for permanent usage.

5.7 Recommendations for Suppliers

As the research has shown, dentists and laboratories care about quality and the best treatment possibilities for their patients the most. It is recommended to closely collaborate with them in the development of the materials. The involvement of universities could support the development of printable materials, as they have capabilities and shared interests to improve the treatment possibilities. They also could create special programs together with patients that are willing to try out new technologies.

As an example, Ms. Mang Buckman stated that the University of Zurich practices student courses, where new treatments are tested. Patients get the treatments for a considerably lower price but need to invest some of their free time to work together with the dentistry students. It has been found that dentists tend to track university studies and research, especially when it comes to incorporating new technological processes or products into their practices.

A further topic which became evident from the discussion with laboratories, was the usage of recyclable material for the try-ins. The current printable try-ins are printed from plastic. At Adent Group this was one factor they criticized related to 3D printing. Currently they do not have the possibility to recycle the plastic used. Therefore, it is recommended to further develop the material for try-ins, that they can be recycled at least.

Another recommendation with the development of new materials is to develop it with different shade possibilities. Currently a lot of dentists let the tooth in the high aesthetic area be made by a dental technician as with the milling, different shades cannot be reflected properly. If the printer would print the tooth crown in exactly the different shades of the tooth next to it, this would be a massive improvement and would enable them to increase the service for their clients.

5.8 Recommendations for Laboratories

Especially for laboratories, that produce dental crowns daily the Additive Manufacturing presents many advantages. Materials can be fully used, there is no creation of waste and there are low maintenance costs of the printer compared to the milling machines. It can only be recommended to inform about and get in touch with 3D printing. Especially with increasing costs of raw materials and rising global competition this new technique is seen as the future in dental production. To avoid any missed opportunities, it is proposed to start the dialogue with their dentists. As they are their clients, it is crucial not to overwhelm them with the topic when the breakthrough of the technology will take place.

5.9 Recommendations for Dentists

The advantages of Additive Manufacturing in the dental field have clearly been demonstrated in both theory and practice throughout this thesis. Hence, dentists are recommended to inform and educate themselves about the new technology. 3D printing is still in development in the dental field, but companies such as Stratasys are working hard to make further progress. Experts from the interviews who already have made experiences with 3D printers, either in the laboratory or as a dentist, made the statement that the future will lie in Additive Manufacturing. The earlier dentists get in contact with the new technology, the easier and faster will an implementation be, when the materials and health certificates are available.

The supportive factors in the model are very essential and should be taken seriously by dentists. Employees play a very crucial role for new processes and their successful implementation. It is recommended that also the employees are motivated by dentists to continue the process of education. Since the analysis has shown that digitalisation does not stop at dentistry and is developing very quickly, it enables dentists to guarantee that they offer their patients the best possible treatment options.

6 Conclusion

The main purpose of this paper has been to discover the relevant factors for a large-scale implementation of Additive Manufacturing in Switzerland. Not only has the research of this thesis shown that technological advances in printable materials are needed, but also that studies to the materials are enormously important for dentists. Training centres, where dentists and laboratory managers can try out, test, and learn how to work with 3D printed materials are seen as inevitable to gain support for Additive Manufacturing. It also revealed that adjustments to the tariff system would be necessary to create incentives for a large-scale implementation. According to the findings and the discussion, the current tariff system of the Swiss Dental Organization blocks the introduction of new technologies because there is no financial incentive with fixed tariffs for services and products. This is ultimately at the expense of customers, who currently have no choice about different treatment options. This research has shown that Additive Manufacturing has many positive aspects. It has also been confirmed that it can have positive impact on the cost structure. As revealed in the introduction, low-income groups tend to avoid going to the dentist because of their income situation. Therefore, the Additive Manufacturing poses a solution to this problem and possibly could increase the well-being in the dental area of people with low-income.

In addition, it got clear that an introduction of the technology needs several important support factors to be successful. The creation of a common vision among all members of the dental surgery or dental laboratory is beneficial. Furthermore, it got clear that the involvement of employees into the decision is crucial and that they should receive enough training, support and understanding from the management side. In the end, the higher their motivation and efforts to improve the printing technology is, the higher is the possibility of a successful transition towards 3D printing.

Related to the topic of centralization or decentralization it became evident, that this question cannot be answered easily. The reasons are that there are very different practices. Some dentists order all crowns to be produced from the laboratory, other dentists only do this with crowns in the high-aesthetic area. This means, there is already an existing partially decentralized production. It occurs that for a full decentralisation, the variety of treatment methods is as of today to broad. Therefore, the research revealed that

to perform those services a dentist would need to employ dental technicians. With this, risks in the form of volume risk, employee risk and quality risks would become evident. As there would be such a high uncertainty, a full decentralisation without any laboratory seems currently as simply not justifiable and would bear too many risks.

6.1 Limitations

There are several limitations acknowledged to this research, which in turn results in further research opportunities. A critical limitation is connected to the fact that geographically only dentists and dental chains from Switzerland have been interviewed. Therefore, treatment methods and materials used internationally for producing tooth crowns could heavily differ to the treatment methods used in Switzerland. Another limitation is that the current state of the additive technology has been considered. If there are ground-breaking advances in 3D printing technology in the future, that for example one printer can produce with several materials and in different procedures, further research would be inevitable. Another limitation is that only the views of the service provider have been analysed but not the customer expectations.

6.2 Further Research

Future research is necessary to validate the conclusions of this study. It is recommended to further analyse the development of 3D printed materials for dental usage, to be able to predict in which foreseeable time the new manufacturing technique will be ready for implementation on a large-scale. The present research solely includes insights from dentists, laboratories and 3D printing companies. Therefore, it is recommended to conduct additional interviews with dental customers. With that it could be clarified if a willingness among customers exists to try out dental crowns printed with Additive Manufacturing. This would further help dentists and laboratories in the decision making of changing their current production processes.

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Appendix

Appendix A: Interview Guide of 3D printing companies

How and why did you enter the dentistry market?

Innovation Management

What are the new possibilities for your customers with your products? (Waste reduction, printing accuracy, production time)

Quality Management

For which uses are the printed tooth crowns currently usable for the dentist?

(Is it already possible to print dental crowns for the permanent use, do you think this will be possible, Materials)

Cost management

Which effects have your products on the cost structure of the dentist?

(Material costs, electricity)

In which way is maintenance for the 3D printers required and are there parts which need to be exchanged on a regularly basis?

If yes, by whom and is it easy or difficult to do that?

Process Management

How are you supporting the customers in the implementation of 3D Printing?

(Trainings, courses, maintenance information)

How do you acquire new customers, and which is your target group?

(Laboratories or Dentists, Collaborations with associations, sales personal, personal visit, contacting by phone?)

How do you see the change through 3D Printing in the dentistry in 5years?

(Which changes/progress are you expecting through the Additive Manufacturing)

Appendix B: Interview Guide of dentists

Process Management

What is your current procedure when a customer needs a new dental crown?

(How often do you have customers which need a new dental crown, looking at one calendar year?) Further processing after arriving?

(How many visits are necessary on average until the new dental crown is in place)
(Follow up question if not answered)

Do you think that 3D Printing could facilitate the process of producing dental crowns for the dentistry? Why is that?

Quality management

Which materials are primarily used to produce the crown?

Is this depending on the customer?

Cost management

On what factors are the costs based of the dental crown?

Innovation Management

Would you see yourself as a traditional, modern, or innovative dentist? Why have you identified yourself as such?

Do your employees have several trainings in the year, where new methods or technologies are presented?

Do you expect that there will be a lot of changes in the dentistry in the next five years through Additive Manufacturing? Could you elaborate on that?

Appendix C: Interview Guide dental laboratories

Process Management

What is your current procedure when a customer needs a new dental crown?

(Which are the steps until, the product is finished, timeline until product can be sent)

Which machines are involved, is there already Additive Manufacturing in parts of the production)

(Do you often need to readjust the tooth crown, after you sent it to the dentist for trying out in the customers jaw)

Have you ever thought to partly integrate Additive Manufacturing into your production process? Why is that?

Quality Management

What would you say are the main difference between a tooth crown form the 3D Printer and a traditional manufactured one in the laboratory?

How is the collaboration with dentists regarding the exchange of information to improve efficiency?

(Frequent exchange, optimization, how big is the customer portfolio)

Cost Management

According to your view, has the Additive Manufacturing positive effects on the cost structure in the production of a dental crown?

Innovation Management

What is your opinion towards the Additive Manufacturing and its new possibilities?

(Dental association, presenting new possibilities)

Do you see limitations in the 3D manufactured products (especially tooth crowns)?

(Only for several orders at the same time -> efficiency)

Appendix D: Interview with Andreas Langfeld

Interview Partner:	Andreas Langfeld
Role	President Europe Middle East Africa (EMEA)
Company	Stratasys
Interview Type	3D Printing Company
Date/Time:	14.04.2022 / 13:30
Interview Duration	31 Minutes 23 Seconds
Interview Language	English
Format	Online

Bolliger Martin (bollima2)

We start with the interview. I would like to introduce myself again shortly. My name is Martin Bolliger. I'm now in the last semester of my bachelor thesis and my topic is centralization or decentralization regarding 3D printing. And I decided to focus on the dentistry industry and especially on the production of tooth crowns. So I'm looking into there in more detail. And my my questions will be regarding innovation, management, quality management, cost management and process management. Probably before we start you could shortly give me some background details to yourself, where you studied and to your business background.

Andreas Langfeld

Yes, sure. My name is Andy Langfeld. I'm now the president of Stratasys EMEA. I started in Stratasys, in 2009. I was going to university in Freiburg in the South of Germany where I studied linguistics and economics. Then I went to the US to work for a start-up in San Francisco and then I ended up in Stratasys. Stratasys is a provider of 3D printing solutions. And historically, 3D printing was mainly used for prototyping and various industries. So if you want to introduce a product, you start with a prototype and 3D printing was back then the best way from cut design to a 3D model in your hand to verify the functionality and the look and feel of your final product as a prototype. But it also evolved quickly that the solution has been finding vertical inroads and dental is only one of them where we now have a dental specific or dental specialized products that are focusing on the real needs of the dentistry industry.

Bolliger Martin (bollima2)

OK. So and then my question will be how and why did your company actually enter the dentistry market?

Andreas Langfeld

Because when you look at Additive Manufacturing in general for many, many times, it used to be limited to the lot size of the parts that you need to produce and hence it was being used in prototyping where you need a few iterations and you do not get produce millions of products.

And dentistry or the healthcare sector in general is very suitable because the lot size of the human body is 1. By definition, all of our anatomies are unique. So especially when you look into dental applications, you have your own teeth and they're unique and that's where you usually only need one model, but it needs to be very accurate and it needs to give you the the real patient situation in terms of surgical planning or treatment planning.

Bolliger Martin (bollima2)

Yeah. So my question, will be what are the new possibilities for your customers with the new products?

Andreas Langfeld

So that the I mean you new in terms of additive what additive allows you to do is to look into different applications within dental. There is a solutions for implantology solutions like implant model search, surgery guides or gingival mask. You have solutions for the orthodontics which is mainly the models or indirect bonding trace you have solutions for removables also the models but also RPD frameworks. The customer impression trays, try ins or as you leave the to the Crown and bridge where it's basically all about the model. So the quadrant or the full upper or lower jaw with removable dice. So if if you if you think about the problem bridge you need an accurate model you need in some cases not in all cases biocompatibility in terms of the material. But not what we're doing with the advancement of the technology is also to offer a colour options. So you can choose between 500,000 colours, for example, which means you can create models, which are reflecting not only the Flesh part but also the teeth part that you can choose the tone of the teeth because in some treatments when it's about veneers or something like that you would also like to see what would it look like when you when you put the final product into your mouth.

Bolliger Martin (bollima2)

Or is there already the technology so far that you have the possibility for permanent tooth crowns which can already be placed? Or is it so far just the modelling?

Andreas Langfeld

It's so, so far, it's just a modeling. The main applications that are being used today is on the one hand, the most widely adopted is the clear aligners. So the the application used to be that you still have the classical stone model. You ship the stone model to the dental lab and then they treat or they they finish the stone model and then they do the vacuum forming with the clear liner material and then you cut the clear liner material and so forth. And now the stone model was basically being replaced by 3D printed models. So especially with the advancement of intraoral scanners so that the the 3D printer is capable of printing whatever data you have, the more accurate the data, the more accurate the printer will obviously work. So the quality of and also the the scale and the adoption of infrared scanning is now boosting a little bit the use and the adoption of 3D printing. Because you don't deliver stone models anymore, you deliver data and you can, as you said, decentralize and print locally wherever you need it.

Bolliger Martin (bollima2)

When you now look a little bit further, do you see that there will be soon the possibility to print with zirconia? Which is the mostly used material for tooth crowns currently.

Andreas Langfeld

I think that there will still be a barrier. We already have materials that you can use temporary in in the mouth, in the patient's mouth. So we have the biocompatibility certification for 48 hours, for example. But if you look for something permanent, I think this is it. It will happen in the future and the technologies are not there yet and it's mainly it's mainly around the material certification, biocompatibility, certification, but also material property and safety certifications. So that's obviously developing that is that is happening. So the more you can go from from bypassing the direct production, but you offer the work around with 3D printing, then that's obviously the the goal that we have as a supplier to innovate around those materials, the same counts by the way for the direct printing of clear aligners. So you don't work with the stone with the model anymore and the vacuum forming you work directly with the Data. Uh reversed the data, so you basically print the clear aligners up directly and then you can use it also in the mouth with the required certifications and so forth.

Bolliger Martin (bollima2)

OK, so if I understand it correctly, it's at the moment more the problem, the certifications or like or your companies also involved in the research to further find out about the materials that they're fitting or?

Andreas Langfeld

So it's both. But basically we need the material that has the mechanical properties to withstand the requirements. And we need to work on the industry specific, in this case dental certifications and we are involved in both. So, we would select either develop our own developed the material on our own or partner with the big material guys like BSF, Henkel, Covestro and so forth, whoever is relevant and then we can choose from our technologies where five technologies, Additive Manufacturing technologies that we can leverage. And then the question is always which one is best suitable for the relevant use case and dental where you need a higher level of accuracy. The way you need a smooth surface, it would rather be a polyjet DLP or stereolithography technology. And then we take it from there and look which material runs best on which technology and how do we do the certification. Do we need to do autoclaving and do we need to do sterilization or sterilization allow as being part of the process and based on that we would put it on our road map in terms of next developments.

Bolliger Martin (bollima2)

OK. And if we look now so far what is possible with the modelling, So what would you say which effects have your products on the cost structure on the dentist? Is it way cheaper to the stove modelling?

Andreas Langfeld

Yeah. Wait, it is a market with a very high cost pressure. So if you if you look at the model. And if you look at the quadrant or whatever the cost per quadrant used to be or the cost target used to be €8.00. Now it went down to 2.5. So we need to be able to offer the price paradigm that is attractive for the dental labs to switch from traditional, which is the stone model to additive. And what we see that by applying Additive Manufacturing, you're basically eliminating delays and inaccuracies of the manual label. So the manual process you can imagine, there's always room for error. So there's a risk that the accuracy is suffering. You have not only the delay because shipment is always taking time, the shipping of physical goods and it's also having a cost implication. Now nowadays where the cost of shipping is going up and you if you work now with the centralized production and you need to ship it across the globe even then it has a huge impact on the cost structure. But if you have a decentralized production with Additive Manufacturing machines or 3D printers across the globe and we have data that is being shipped and not the model as I said before, it has cost saving implications. One is shipping, the other one is also cost of error as I said because the manual process may always include error.

Bolliger Martin (bollima2)

Another question in this regard would be, in which way is maintenance required for the 3D printers or are there parts which need to be exchanged on a regular basis or how does that work?

Andreas Langfeld

You can almost compare it to 2D printer. If you have a 2D printer and a professional

environment like an office environment. The requirements that you have you need to have trained staff which is less relevant for 2D printer because most people know how to use it, but it's also with the 3D printer if a non-technical guy like myself. If I can use a 3D printer then it's OK. So, it's not too complex but you get training from us, we install the machine, we train the operators. And then obviously you have consumables materials that you need to replace and it's a bit more complex on that. And then a 2D printer in terms of the print head or the lasers that are being used depending on the technology and that's where you have a certain degree of self-maintenance. So, you will be trained how to replace certain consumables or wearables. So that need to be replaced based on the consumption based on the usage and otherwise we have our service network also with two different companies have and if there is an issue which is non-consumption related then we have our service offering and our service proximity to serve the customer in short time frame because dental it's in production environment and the prototyping you may have you know more patients and if there is an issue and you get a service a technician in the next week, it would be sufficient, but in dental it needs to be 24 hours. So we need to secure that proximity to the customers and that service level agreement.

Bolliger Martin (bollima2)

A further question to get a little more in detail like the energy consumption of this 3D printers, how does that look like? I just read that once they are quite using a lot of energy, but there was also a lot of change going on.

Andreas Langfeld

Yeah. Well, it's an industrial machine. So, it's comparable to other industrial machines. Uh, based on the product we have, you know, we have 3D printers or Additive Manufacturing machines that are very expensive in terms of the CapEx investment, and they are really machines that require heat. That require a lot of power consumption, but it's the corresponding output and it's not more energy consumption than traditional manufacturing methods. On the one hand, and on the other hand, if you look into our solutions that are being applied more in an office environment and or in a lab environment where dental would be the similar target market, I think that's where you see that the consumption of energy is not in line with industrial machinery. It's below. More in line with the heavy office equipment.

Bolliger Martin (bollima2)

OK. Then my next question, you almost answered, but how do you acquire new customers and which is your target group currently?

Andreas Langfeld

That's a good one because historically we are not a dental company, right. So we are selling to the automotives, to the aerospace and industrial machinery, consumer electronics, consumer goods. And the dental market is another beast. So if you are not able to speak the language of the dentists or the orthodontics or the dental labs, you will not be considered as a trustworthy supplier. And that's why we need to make sure that in our go to market, which means in our customer facing organization, we either work with the right partners that are dental experts or we hire the people that have dental knowledge. And that's what we started a couple of years ago. So, we have our own dental experts in my team. We have companies that are reselling our products, which are also selling other dental equipment. So, they really target the dental labs. Umm, in in Europe in general, it's a pretty fragmented market. So you have a few larger labs, but you have a whole bunch of small labs and that also means that we need to adapt our offering to the European market in a way that you have lower end solutions which are more affordable for smaller labs. But you also have the high-end solutions where you have a higher throughput,

more variety of versatility in terms of the applications that you can serve with the single machine. And that's our offering to the larger dental labs.

Bolliger Martin (bollima2)

But there is so far no targeting that you also directly go or contact dentist by itself. Like if you look a little bit further do you think that there is the possibility that they can manufacture everything in the dental surgery?

Andreas Langfeld

That I mean the first of all they are definitely part of our target group because you need to, you need to also convince or have the right message messaging for those that benefit from the technology in the end and in the end it's always the dentist that is benefiting either by reduction of time. And that's why we need to basically win the minds of the dentist, because then they will have the requirement that their suppliers are using additive because they're convinced about the benefits and they basically if a dentist says I have a better patient care, a better patient peak treatment. If my suppliers are using at using additive, that's the goal that we want to achieve and the rest is the tier one, Tier 2 model where the suppliers to the dentists are adopting the technology in order to support the dentist to provide better patient care. But if if you look into the future , there certainly is a dream that each dentist would also have a 3D printer. The question is, what is the market dynamics? Is the dentist willing to take more in house because where do you start and where do you stop? If you, as a dentist, would like to produce everything you need in house, you need double the size of room. You need to have your own small laboratory. You need to pay the staff. So I think there will always be an outsourcing element and the dental labs will always have their relevance.

Bolliger Martin (bollima2)

One of the last questions is one you almost answered. How do you see the change through 3D printing in the dentistry in five years? Where do you see the Additive Manufacturing, let's say of the market share or like how much will be in the dental laboratory be used using Additive Manufacturing?

Andreas Langfeld

It's very similar to other industries and dental is a very good target industry because again of the lot sizes that are required. So how many models, how many parts do you need, how many patients are being treated on a regular basis? And I think that's where the future is to capture more and more applications within dental by directly producing additively. And now if you look at 100 applications in dental, there is probably a 40 where we drive efficiency within the process. Now there need to be at least 10 where we are the production method of the future. So we are the way how to produce dental components that are required. And there is another 30 where we are offering the efficiency to the to the workflow. And I think if you look at into this as a percentage. So I think if if we play in 50% of the dental applications, it will be a huge market and additive will require to be very focused on dental and to bring more dental tailored solutions to market.

Bolliger Martin (bollima2)

OK. And probably to catch up a little bit, when you said the dentistry, it's very difficult environment if you don't talk the right language. So what was it like in the beginning of the company when you entered the dentist market. What were the reaction of the dentists or the

laboratories? Were they willing to see this opportunity or was it rather difficult as you mentioned that you need to speak the right language?

Andreas Langfeld

I mean the good thing is that they're all very educated and smart people, so they could really relate to how Additive Manufacturing can bring value to dental. And they have been offering us help. How do we need to design our products? How do we need to define the materials that are being used. But I think it was a classic case of where the customers collaborated with us in order to advance our solutions. And that is still ongoing. We have very close connection to very to many thought leaders within the dental industry and they are helping us to improve our products to market tailored for the dental market. So there has been an immediate understanding that additive can help and also the willingness to support how to make it dental specific. And that was helping to for us to now, if you look into dental as a separate market where we have a dedicated business unit where we have dedicated products. And where we continue to develop materials and printers and software solutions cause it's also in in certain dental applications you need to get from DICOM to cap file or to additive printable file. That's where you need segmentation software where you need to have software where you can identify the colour which colour do you want to see on which teeth. So I think this is all helping to further advance and continue to continuously advance our solutions.

Bolliger Martin (bollima2)

The intraoral scanner there, I read that there is a software behind which is often connected to the 3D printer and it's only working with the related software. Is your company then just collaborating with an intraoral scanner company or how do you make there the connection?

Andreas Langfeld

But we are allowing a native cut design to be applied with our printer software. We have our graph card, printer software and you can look at it as a PDF. You can translate word documents, excel, PowerPoint. You can all translate them into PDF. So our software is the PDF enabler and you can take different data from the data from different intraoral scanners or different cut sources or 3D sources and apply them to be printable on our machines.

Bolliger Martin (bollima2)

So it's working with every product actually? One last question, how is the competition like I saw a lot of companies who are entering the market. Do you have a competition on a global scale or more country by country?

Andreas Langfeld

Yeah, yeah. So first of all, there was still a lot of exploration. So you will find in local markets you will find companies using local 3D printing suppliers. To do some models and to test the capabilities of additive and that's where a lot of solutions are good enough. Umm if you then want to take it into production efficiency or into producing parts. If you need to achieve biocompatibility and so forth, then it really narrows down to a couple of suppliers, but there is now there is a good landscape of 3 D printing suppliers offering solutions into dental and they are yet targeting in some cases on similar applications and other cases on very different applications. So I would say that yes, there is competition, but we are just scratching on the surface of the dental market potential. And once we open this up, you know it will be a tiny competition again compared to the market size that we have ahead of us. So there will be very

good business for all of the 3D printing suppliers. The question is, do you focus on the specific applications, do you focus on being able to offer a broad set of web applications, so there will be certain cutting points between the competitors, but the market potential is very huge, so I don't see a dental competition density in that sense.

Bolliger Martin (bollima2)

And probably one thing again to the certifications. How will you get them like is there an organization which certifies the material? Who will give you then the certificates when it's in the future. possible to have such a materials which can be used permanently

Andreas Langfeld

I mean in in principle you have from the health organizations that could be local, it could be European, you have or it could be in the US you have certain certification requirements that you need to fulfill. If you look at skin contact or tissue contact. You need to have standard. You need to to pass through standard certification programs or procedures and we stick to those. So it could be local in some cases, but most of them are also in the alignment between the US and Europe. So most of them are really standard and you may have small variations, but we don't try to grow local and then scale upwards, we always try to take the hardest qualification 1st and then we are safe for the rest.

Bolliger Martin (bollima2)

Yeah, I think that was more or less was more or less it. So thank you very much for the time. It was really interesting and probably one last thing like the the support that you mentioned trainings you give like online trainings or how do you support?

Andreas Langfeld

Pleasure. We have both. So first of all, when we install the printer, we have people that are physically with face to face training to the operators because you open the machine, you show them how to replace the printer for example. And then we also have an online training offering with our STRATASYS as Academy. But we also have training webinars, or we do remote support either application support or Technical Support. So we are offering the full package

Bolliger Martin (bollima2)

So thank you very much. It was really interesting to get some insights because the theory often says also a little bit different things than it's in reality. So that's the idea of my thesis. But I read just before that there is like in a paper that it's already possible to really print all these dental part crowns in the in one place but.

Andreas Langfeld

It depends. I mean for example we are a company that is very focused on polymers, but you also have companies that are focused on methods. So there, there is indeed companies that are able to print metal crowns. Now the question is how and that's why? Talk for them, but. Is it economically viable. Is there an economic benefit is it compliant with the health regulations. Is skin contact allowed or tissue contact aloud. I don't know, but. But there is there is technologies out there from competitors that are able to print crowns probably also in the required detail maybe yes maybe no I don't know. But there is also metals used. So I wouldn't by definition say that it's impossible. But I cannot speak to the others. I can just say our focus is on the polymer side, the clear aligner printing is a very, very attractive solution that we are after. And besides

that there is tons of applications that we can fulfill in polymer either for the direct use or for the workflow optimization. And what would really help is if intraoral scanners are getting more accurate than the affordable.

Bolliger Martin (bollima2)

Are the intraoral scanners, the expensive part then?

Andreas Langfeld

Not, not expensive compared to the printer, but if you think about it has, it has improved, but the couple of years back and a good or a good enough intraoral scanner that provides good data was €30,000. Now I think the prices have gone down and the quality has gone up, but the more they advance on their or scanner side, the more you will digitize the dentistry.

Bolliger Martin (bollima2)

So it's depending on each other. And what is the price range if we talk of the printers?

Andreas Langfeld

Price range if. If you really want to have one for dental applications with the with the right level of repeatability, accuracy and throughput, probably 50,000.

Bolliger Martin (bollima2)

But they also went, massively down, right, compared to the past.

Andreas Langfeld

Absolutely, absolutely.

Bolliger Martin (bollima2)

Then I would stop right now the recording.

Appendix E: Interview with Fabian Frei

Interview Partner:	Fabian Frei
Role	Business Developer
Company	Swiss Smile
Interview Type	Dentist Chain
Date/Time:	22.04.2022 / 09:00
Interview Duration	1 hour 07 Minutes 56 Seconds
Interview Language	English
Format	Online

Bolliger Martin (bollima2)

Before we start, I would like to shortly introduce myself again. My name is Martin Bolliger. I'm in my last semester of my bachelor's in International Management and my thesis is concerned with the strategic decision to centralization or decentralization with Additive Manufacturing. I therefore decided to look more in the dental, healthcare and more specifically in the manufacturing of tooth crowns. And my questions will be regarding process management, the quality management and cost management as well as innovation management. And I try to find out along the whole supply chain what are the factors which are essential that the Additive Manufacturing technology will be implemented on a larger scale. And probably before we start with the questions, you could shortly also introduce yourself and give me some insight of your professional and personal background.

Fabian Frei

I am looking forward to this interview. I have started working at Swiss Smile in December, but I'm 10 years in dental. And before that, I studied business management at the University of Saint Gallen. And currently in my role I'm the Chief business development of Swiss smile and I focus on. Well, it's a very broad field, but it encompasses marketing. Which is really nice because you know patient acquisition is one of our most important tasks. And it also involves very clinically focused topics like for example, you know introducing new treatment modalities or improving processes that have a benefit for the patient, the dentist, and the clinic. So it's a very wide field and you know when it comes to laboratories and prosthetics. This is something that the company Swiss Smile has been looking into more last year. It's not a focus at the moment, but it's definitely something that we still can work on to improve. But it's a very helpful discussion also for me.

Bolliger Martin (bollima2)

Yeah. Perfect. So then probably I would start with the first question. What is your current procedure when a customer comes to your practice and would need a new dental crown?

Fabian Frei

You know, we have like usually patients, they don't come and say I need a crown. So in their mind they just have either pain or they have had some issues with the teeth they go to the dentist or they go to the hygienist. Then they start telling the treating personnel what's wrong with them and the dentist based on what they see clinically, meaning in the mouth or on the X ray they recommend an option for treatment. And a crown is in the life cycle of the tooth, it's actually not the first step. Usually it begins with caries lesions, which develop into cavities, and then the

dentist has the option to use fillings. That's like the first line of defence. And after that, fillings last between 10 to 15 years, some might last longer. Often secondary caries develops. Either it can be redone or if the tooth is too impacted and the dentist might recommend doing a crown to basically. And avoid future issues because once the tooth is filled, the structure of the tooth is impacted so much that it can break. Because the walls of the tooth get thin, or sometimes they get, you know, drilled away and filled with materials. So what? What happens after the fillings? It is often the case in 20 to 30, long term years, there is the need for a crown. It could be that you need a crown directly if the tooth is, destroyed beyond hope, you know, if you have like a huge cavity and there is no point in reconstructing it with composite material, you might go with the crown directly. But there is always a discussion with the patient in terms of these are your options and also this is the price because there are different prices depending on what, treatment you choose, and the Crown is far more expensive than a filling.

Bolliger Martin (bollima2)

OK. And if the decision is made to get the customer a crown, how is it working at Swiss smile, will the dentist send an impression to the laboratory or how is there the process so far at your company?

Fabian Frei

If it's decided that the crown is the best way to go forward and this has been agreed to by the patient, I mean we have a lot of practices, right? So I can't. I can't give you like, I mean, there's differences in each of the practices depending on the treating doctor. But in general, the process would be that the dentist starts. Prepping the tooth. And of course he does. So we have like 2 technologies we have scanning technology or impression taking and we have the normal impression materials for doing the impressions and if you choose a digital workflow like scanning, maybe we take that first. You have the possibility to capture the shade and of the tooth with the scanner, but most dentists actually try to take a picture as well using a special device because it's not. It's, you know, yeah, it looks different on a scan than it does in reality. And if you have especially a crown or something in the front, you want to make sure that the colour is exactly right, because otherwise even a small change in the shade, everybody will notice it. So if it's in the aesthetic region. And then people will usually do a picture with a quality camera or their mobile phone and a special lighting device. I don't know the name of the device right now. And they will use this information with their dental technician to determine the colour. Some might even have the dental technician come in and take the colour themselves, because they will produce the crowns in the end. So you prepped the tooth. And then you take an impression, and you send it to the lab. The lab is starting to manufacture the crown digitally or manually. Basically, they just convert the normal impression to a plaster model and then they scan it sometimes and work digitally or they use a manual workflow. You might have already. Described it in your thesis and. And then the Patient gets a temporary crown. Which is done, you know, like, cannot be done in house with a milling solution from Zirconia. Or it's just composite material. And once the Crown is finished and sent back by the lab. There is a seating and session where the temporary gets removed and the patient is fitted. The new Crown it's cemented on top of the preparation and made sure that the articulation works so that they make sure that the contact points aligned that there is, you know, even 50 microns and you bite is completely off. So that's the important part. If they have been working with the laboratory for a long time. They know that the crowns that come back usually fit, and the adjustments take very little time. Three to five minutes, maybe no. And that's the most important thing, because the time for the seating is, you know, is determined and if you need to grind and change and have problems, then that's like the biggest barrier to adopting a new laboratory or even new process. That's really the biggest barrier, and you need some time because the crown depends a lot on the prepping of the tooth by the dentist and that's very

individual. And I mean there's theory about it how to do it. But the reality is that every dentist does it a bit differently, and when you switch a lab or choose a new technology, you often have a time where you need to learn how it fits in the end.

Bolliger Martin (bollima2)

But like what is he doing differently? Like way the how he treats? Or so I didn't got that completely like he's preparing it differently or the material or after it comes from the laboratory or.

Fabian Frei

No. So he preps the tooth. So I'll show you quickly the tooth.

Try to draw it. This is a cavity or whatever, right? And now we decide to prep the tooth. What I mean by that is he will cut off. This part right and see these lines here.

Fabian Frei

That's like the prep line, and he can choose to do it like this. Or like this, you know? And or he might choose to have a higher chimney here. Right. So that's individual. And that makes that has an impact on how the final crown will sit, whether it will be flush, whether there will be borders and all these kinds of things. And this they learn it the in university and of course, when they do practical work at university, they also get taught how to do it and so on and so on. And there is huge differences still in the way that people prep teeth. And that has a big influence on the crown, how it fits, how long it will last. And it's very important factor and. This is something that, yeah. That is actually important for quality control, but how do you control that?

Bolliger Martin (bollima2)

OK. Yeah, I see. So the laboratory needs to get used to the working practice of the dentists and how he wants the crown or how he's cutting it there.

Fabian Frei

He need to adjust exactly, and they can't tell the dentist. Say your preparation is wrong or it's not good or should have done it differently because there is dependency between the laboratory and the dentist as well. Some labs might be able to do it, but you need to. Yeah, you need to be strong character to tell a dentist. You know that they should maybe do it a little bit differently. The preparation of the tooth is the most important part of the Crown process.

Bolliger Martin (bollima2)

But it's the dentist, and after he cuts this prep line, he makes the picture and the scan to see how the Crown needs to be built, that it's fits perfectly in the mouth, or is that happening often?

Fabian Frei

He just preps it, so he does like this chimney that I showed you and you know, chooses the. That makes the border so that the crown can be put on top. And then he basically just scans or takes an impression, and he checks the margin line. They need to be sharp. So you know the line around where the crown is put on top. It needs to be sharp. It can't be like it needs to be straight, otherwise you don't have a proper content. He checks that of course visually then, when he scans, for example, he just in the end marks the line for reference for the laboratory, but they

can change it depending on, you know, whether they think it needs a little bit less but, he can still define the prep line. And then that's it. He sends it to the lab, and the lab does everything from building the morphology of the tooth to making sure that it fits perfectly. That's really the laboratories work, and the dentist relies on the lab to deliver the crown. That will really fit on top of this prepped tooth and that it will allow for the cementation because you need to put cement in, which has a certain thickness. So they take care of all this. The dentist basically doesn't do anything afterwards. He doesn't design the tooth. Or he doesn't like give input on how the tooth should be prepared. That's really the lab. So that that's why the relationships are quite strong. Because if you have a good lab that can deliver that. All the dentist has to do is to actually fit the crown in the end, seat it and cement it and make sure it's articulating correctly. And then the patient can go out and has a restored tooth again. The dentist can do this in House. There are dentists that do the design themselves. But those dentists are usually, highly, you know, motivated to, I mean they vertically integrate into the or horizontally integrated into the labs field, right. And there are some dentists that do that especially if they do crown in a day. So they might have Cerec where they designed the Crown first they use usually algorithms to give a suggestion of how the tooth could look like and then they make adjustments on it once they lock this they can mill it in two hours. It's done and they can see it directly with the patient. But usually it's the labs work.

Bolliger Martin (bollima2)

But is this does is that just for the ones who are not permanently placed or also the permanent crowns?

Fabian Frei

The design and the process. Also, the permanently placed once.

It's called in dentistry. In English, they would call it a crown in a day or tooth in a day. And yeah, it usually takes 2 hour for the finalized restoration to arrive, depending on what materials you use for the crowns, you can have materials that you need to sinter in the end, like burn so that they get the right volume and hardness, but there are materials that just need to be milled and then they can be seated.

Bolliger Martin (bollima2)

OK. And what materials are these like?

Fabian Frei

Straumann group. Yeah, so they have a material which is called Nice. I'm not sure if they still call it that way, but it was called Nice. And that's, for example, a material that you can combine blocks for those milling machines. And then you just have shades that basically are reflecting the shades of the teeth. Usually, they use the Vita shade system, which I think has 16 colours. And they choose the shade depending on what they see in the patient's mouth. They mill it and then they directly seat it.

Bolliger Martin (bollima2)

OK, so this goes already in the direction, so they also use Additive Manufacturing there already or.

Fabian Frei

But I'm not sure what you mean by additive technology. I know everybody wants to be able to print crowns. With the 3D printer. But I haven't really heard of anything like that it's possible. I know they are all researching this. They're all trying to come out with a printed crown that can perfectly reflect because the tooth usually has several shades. It's a bit darker. You know where it touches the gum line, and it gets brighter as we go up. So, it's not one colour actually. And if you could print the tools, you could even reflect the change in colour and make it perfect copy of nature. And yeah, with 3D printing technology becoming you know Chairside available. Everybody, I think wants to provide this kind of business model because it would be super attractive especially for the suppliers that work mainly with the dentists. But it's extremely hard to uh print ceramic materials. I'm not sure if you tell me differently, but I it's not in the market yet that that I'm 100% sure that it's not yet available on a large scale.

Bolliger Martin (bollima2)

What I found out so far, I had one interview with a 3D printing company. Is that like they have so far just the certificates which they could last 48 hours, which are biocompatible materials for in the mouth, but they are on it. But so far not. But I heard that companies are already quite far progressing with zirconia. I think it's widely used and I think they making quite big progresses that printers in the future are able to print zirconia crowns.

Fabian Frei

Yeah so when I say ceramic, I mean zirconia, it's basically the same. To zirconia dioxide. So ceramic printing. Yeah, I think that's the next evolution step, but.

Bolliger Martin (bollima2)

So you said the better it's manufactured or in the laboratory worked of course the dentist needs less to adjust. But if he needs to adjust, he needs to send it back. Or can he do some adjustments by himself?

Fabian Frei

Yeah he would do the adjustments chairside. So when you look when you look at the at your molars for example in the mirror, right, you have these points there. And the contacts to the antagonist. So the upper part of the teeth or the lower part of the teeth? And when you have it like 5, like a hair, right? So if there if it's too high, your whole bite will not lock and then they will have to use a grinder to basically just clear that off. Then they have a paper, the blue paper maybe also had already bit on you know the. Then they see if there's contact on the tooth. Then they grind it off. They do the same again. They do it again. They do it again. They do it again. And because the material is hard, right, it's ceramics. it takes some time. That's the adjustment that they can make. They cannot internally adjust the crown. Because then they create, you know Bubbles almost. If you have these huge forces from biting. You create stress or let's say you create areas where there is a potential of breaking the crown. So it's only outside that they can make adjustments.

Bolliger Martin (bollima2)

So do you think that 3D printing could facilitate the production of dental crowns? When we talk now about that, you could be able to print the crown chairside.

Fabian Frei

Right now. I mean right now is actually that the lab does the crown. Because the dentist is not a technician. So if the if we had a printer in the office. That could produce a perfect crown. Then

you would still have to maintain the printer. You would need different shades. You would need different mixing powders, and it's a technology device. It can breakdown. It has all these things that happen, and somebody would have to maintain it and take care of the technology. So right now I couldn't imagine having a printer in each office. And because the office would need to fulfil certain requirements like very technologically, uh high tech affinity by the staff. The dentist that is a fan of new technology that really wants to have this, that wants to do this a dentist, that offers premium services to his patients like you know, a printed crown in two hours. So if there is the demand from the patients, if there is a high tech affinity by the staff that they can manage this device. It would be an option. And only if, then the tech delivers what it promises. So like if Straumann came and said to me, hey, Fabian we have this new printer, it's amazing. We would for sure trial it. For quite some time to see if it really works, and if it doesn't, which usually is the case in the beginning. Not because it's just because everything is new. It would take another half a year or a year before we would start again, because everybody would say it's not working. Don't come again, you know, don't. Don't bother me with this. I have my job. This is what I know and so on. So I think it will take quite some time if another thing would be if we would build or own a lab. That can deliver this to our dentists, but that it's like managed as separate unit or we buy it from a lab that's what we are open to.

Fabian Frei

Because then you have taken out, you know, the problem with technology. The problem with maintenance and then if you get a super nice crown from it, even if it takes two or three days. That's something we would be open to, but to these, completely decentralize it. I wouldn't touch it.

Bolliger Martin (bollima2)

But right now, how long does it take right now to the when you give it the order to the lab. So as I understand you have an external lab you're collaborating with?

Fabian Frei

So we collaborate with a lot of external labs and basically with the scanner, it's easy. You basically say you do the scan. You say already when you want the crown back, and of course you it can't be tomorrow. You have to give them a week or something. You can also try 3 days, but if you do it electronically and you basically just select the date of delivery. And then you send everything and the lab has everything, patient information, the scan, the colour. So, he they can just accept and when they accept it, you know it's gonna be delivered on that day, which is usually before the appointment with the patient. So, they have the crown already there because it's not just in time world yet, so they need a safety margin of one or two days. So what's the time? It depends. But three to seven days like quick, but some dentists not in Switzerland. It's very rare, but in in other countries they order it overseas. You know, so they order a crown from a Chinese lab so in Norway there are many Chinese laboratories that have affiliates in in Norway, for example. And then the dentist can choose between a Norwegian crown produced in Norway or a finalized crown in Norway, which actually comes from China. So, you have already two longer because of the delivery time of the.

Bolliger Martin (bollima2)

But like when you give an order so you have then you send it to several laboratories and then one accepts or no?

Fabian Frei

We send it to one laboratory that the dentist chooses in advance. Yeah. So again, from a scanner

perspective. So, in the scanner, let's say the three shape trios 3 or most others. Basically, the first step is to choose the lab and you have to preconfigure the laboratories. So basically, they see three or four laboratories and then they know based on the relationship that they've had with the lab, which order they place at what lab. But you choose the lab always when you place the order. So, there is not an auction or something like that.

Bolliger Martin (bollima2)

OK. Yeah. So that the dentist has quite the flexibility because you offer him several laboratories where he can choose from his order?

Fabian Frei

Yeah, most dentists in Switzerland, whether they are part of a Zahnarztzentrum or let's say a dental chain or not, they have several labs that they work with. First reason is redundancy if one gets sick or whatever. The second is point is for different regions of the mouth you might want to work with a different dentist, because everything that is in the non-aesthetic zone. It's not as critical because you rarely see the molars, so they choose also based on that.

Bolliger Martin (bollima2)

I see. And the materials we probably already talked about, but so are there other materials which are primarily used, is this also a little bit depending on which place in the mouth it's the crown is needed or the replacements. Is this primarily ceramics?

Fabian Frei

So this is an interesting question. Dentists are educated to use the clinically the material or procedure that has the highest clinical evidence. And, you know, ceramic crowns or porcelain fused to metal. That's like you have a metal coating, and then you put porcelain or ceramics on top. And so over time more research accumulates for newer techniques, newer technologies. But when you for example if you would start using 3D printed crowns as of today, technology will be perfectly evolved. There would still be a lot of dentists that would want to see the clinical evidence that it's lasting a certain amount of time that it's biocompatible. That's all this kind of thing. Usually, suppliers bring out these studies when they launch a product. They already have two-year data or five year data or something But still the older technologies have much more research.

Fabian Frei

So dentists the way they are trained. I talk a lot with dentists, I have the feeling because this is the conversation, I have with them. They would tell me, Fabian look , this crown here it works it's perfect. I like it. Yeah, I can't. It's true. So they have a tendency that to choose a technology that's been out there for longer. And that could be in in your view and my view and maybe in the patients view. An older technology and we want to have the newer thing because we don't think like that, right. We think well if they bring it out it has to be at least as good. So that's a little bit the thing they choose the treatment or the materials that they have the most confidence in and that's a mix between the literature that they have been reading and using and what they have been using practically and their own clinical experience with their patients.

Fabian Frei

So that's basically if you go to a dentist, a younger dentist, that somebody that is just graduated

from university, and he works for 10 years. You will probably get a different treatment recommendation, because he has been taught differently than if you go to a dentist that has been working for 30 to 40 year. It's the same in every profession where you have specialists. And you, you could say the same probably about doctors, you know, physicians or maybe even lawyers, so that's just the trade and that that will determine what is used and you don't have a choice as a patient in the sense that you don't know what is out there. So how can you choose? What can you say? I mean you have now you will gain knowledge me as well. I mean, I have knowledge about it. So, I could basically say I don't want this. I would like the other one and if the dentists would say but I don't do it or can't do it, then I might change. But the normal patient will just take the recommendation and the recommendation is based on clinical evidence, so it's actually a good recommendation. But when it comes to newer technologies, it might be a bit behind. You know what I mean?

Bolliger Martin (bollima2)

Yeah. Yeah. It's like kind of. They trust more in the older in what is more studied. So they're the they're the willingness to change takes longer because they need more clinical studies or waiting for more clinical studies until they're ready to test it like.

Fabian Frei

Yes, exactly, exactly.

Bolliger Martin (bollima2)

Because probably they're also scared to lose the image or for or like that, the customer gets mad and because I read or I can see that in the dentistry, it's really a lot based. You're not going to say I'm switching my dentist because often you have a recommendation once and then you go to this dentist and if you're happy, you often stay with that dentist. And it's not like with other services where you very fast switching or able to switch, I think because. As you said, the knowledge is not there from the patient side, so it's really difficult for him to change if it's a good decision or a bad or if he wants a newer option. It's just interesting because I see that. The from the dentist site at the new technologies are often also new possibilities to save costs not only for the dentists, but also would be for the customer cheaper in the end with different materials. But there that's probably question to your side again like is there a big difference now if you talk from a zirconia crown to a metal fused.

Fabian Frei

Do you know that in Switzerland there is by the law no margin on any dental lab work. So if the lab charges the dentist 1500 Swiss francs for the crown. The dentist has to pass on the same price to the patient. Did you know that?

Bolliger Martin (bollima2)

No, I didn't.

Fabian Frei

That's by law. That means the dentist has no incentive. Because that's very special to Switzerland. In other countries, yes, you can add a markup on the crown, but in Switzerland. So the dentist basically here has no incentive to go for a cheaper material. Unless he would like to offer a better price to the patient. But the key things Swiss dentists think primary about quality.

And high price for us means high quality so. Just imagine a normal crown is 1500, and now the lab comes to you and says. I can do it for 500. It's a very steep difference. Very big difference. I would also be a little bit like, yeah, but uh, why did you sell it for 1500 before? And is this really as good as what you're what you gave me before? I'm sceptical. And because you pass it on, and you want the best for the patient and the patient already knows a little bit. You know, he's informed how much it will cost him. He might not always be informed, but if he gets an offer, he will see it's 1500, a 1600, 1300 or so, maybe 2000, and he has already said ok do it. That one that benefits is the lab. The lab can sell a crown for 1500 and produce it for you know, whatever, they benefit.

Bolliger Martin (bollima2)

Yeah, I see. I see. But like, is it not then that they are with the lab make some agreements or like so they're nothing earning at all on the crown?

Fabian Frei

No, no It's complete. It's illegal. So you come by law in Switzerland. You can't do that. You're not allowed to do that.

Bolliger Martin (bollima2)

Has this a special reason?

Fabian Frei

You were asking me a good question. And you will have to do some research on this and then you will find the articles that I don't actually know where it is. Maybe you go to the SSO website. And there it there. It describes because it's also for patients how tax system text point system works and how it has to be passed on directly. It's the only market actually that I know of, because I've worked internationally. Where this is the case. But it's a good thing it's. I think it's a good thing for the patient to be honest. It's a good thing so.

Bolliger Martin (bollima2)

OK, but back to the laboratory can really play around with the prices then do you know that what they are do they have then different prices in the crowds, so like it's the zirconia cheaper compared to the metal fused porcelain or?

Fabian Frei

Well, the, thing that explains the price difference is the amount of manual work that has to be put into creating a crown so you can mill a crown out of zirconia full monolithic. They're called full monolithic crowns. And full monolithic crowns are designed in the computer the file is sent to the milling machine, then it's milled, it comes out and then it has to be finalized and finalization means. Glazed and stained and it's a short process. But then there is also you just create the cap they're they call it a coping so it's like a little cap over this chimney that I showed you and then they manually add ceramics, and they make incredibly beautiful crowns which have, you know, like translucency, like your real teeth. When light shines through them, the lower edges are usually a little bit see through. And all of these. And this takes a long time and it's craftsmanship at the highest degree. That's where the price difference comes from. So a lab can't sell you. They can't sell you or they can't produce a highly aesthetic crown out of the milling machine.

So it needs to be more expensive. They have a limited capability to save costs- They save costs with the raw materials. Basically, whether the use metal or whether the use ceramics and you know metal is usually it's such a small it's such a small price difference we're talking we're talking is it 60 or 70 Swiss francs or 80, you know, it's like it's like not huge savings. There is one exception, that's molar crowns, where you can do full monolithic out of the milling machine. Because that's fully automated and you can buy these ceramic discs. The the price of 1 crown is relatively low, but don't ask me now exactly how much it costs. I don't know it.

But if you want to find that out, you can actually research online on Google. You can find ceramic disks for crowns and then you will for sure find on Alibaba or something. You will for sure find a reference price of. And zirconium disc. And you know, in such a disk you can place. I mean you can look at the size of your own tooth. You can place 13-14 teeth. And that would give you an average.

Completely raw tooth that still has to be refined. Yeah. So you can get a rough estimate and you know people know this dentist know this as well but. In the end, right, you don't just pay for the materials you pay for. I mean, they have a lab setup. They have all these machines. You have all these things, so I think nobody goes there.

Bolliger Martin (bollima2)

But this milling machine is stands just quite similarly to I mean the not how it's produced the production way, but it comes very similar to an additive. Manufacturing printer because like it makes or like a lot of the part which needed to be manually with now in the will be created in the milling machine itself. As I understand like there was already quite a progress compared to the past.

Fabian Frei

Yeah, yeah, absolutely, absolutely. The lab work has changed completely from completely manual. You know, using wax and using metal frameworks and then burning them out and then putting on top of it hand drawn ceramics to milling for the two structure and then finalization. So the manual work has been reduced to the finalization part and the difference with what you call additive. Additive material printing, I mean, then technically the lab could basically create a perfect crown with the translucency it meets at the right areas. It meets completely out of the printer. It would be the next step in the evolution. Because you still not like there's so much, you know, when you do milling, there's dust. There are all these things. It's like the machines are huge. You need a lot of space. They cost a lot of money. They cost like. A smaller unit, a really small units like 50,000 Swiss francs, a bigger unit is 150,000 and if you want to go bigger it can become. You know 12 million and then you can really. Then you have. You can put as many disks as you want, different colours. You know you reduce all the manual steps and make it more automated. But yeah, it's Milling has been very speak changing factor in the in the laboratory field.

Bolliger Martin (bollima2)

And the only thing that dentist charge is then is like his personal work. When he places the crown inside of the patient's right.

Fabian Frei

Yes, yes. Yeah, he places and that's standardized. There is a tariff. So if he does a crown, there

is a, there is a point system. Maybe you go to the SSO and look up the tariff. So that's the dental tariff. And in there all the services that the dentist does are defined. And each service has a point value attached to it a minimum and a maximum point value. A bracket range of how many points he can charge and then he can choose what a point is worth. One Swiss franc is the lowest, but he can go up to 1.25 or something like that so he can add 30% and that's allowed because if you run a dental clinic in Zurich. Well, it's a bit different in terms of location cost, you know different rent price, different things like that and so on. So you can charge higher than if you are, I don't know where do you live, Martin?

Fabian Frei

Wädenswil. OK, maybe in Wädenswil, you know, it's a lower and the service point value multiplied with the tax punkt wert. This is what is on the invoice for your service. Yeah. So that's that's what you get charged and you might pay 25% more in Zurich than you might pay investments feel? But then probably in Zurich, the person that treats you has done maybe more crowns. I can't say that really, but so I think that the price difference it's definitely justified.

Bolliger Martin (bollima2)

Yep, makes also sense that they have a certain range. Which I mean, otherwise it wouldn't be fair. As you mentioned, certain locations are more expensive, so you would have a disadvantage.

Fabian Frei

Yes, exactly. And it's competition. You know, I could or somebody could open a clinics next to you or dentist in Wädenswil and say, OK, I'm I'm gonna do 10% lower but he can only he can change the tax book value. And he can also change the services because he has the range, right? So he can choose the lowest or the highest or something in between. So that's how it works. So yes, the answer is he gets paid for the service of delivering a crown and that includes more than just a crown, right? That includes anaesthesia. That includes putting the rubber then in your mouth that includes several positions, so it's not just one service, it's like an accumulation of services. But that's what he gets paid for and the crown is separate.

Bolliger Martin (bollima2)

And you said that the customers can choose between the scanning or of the if they want to get scanned or traditionally? Because I heard the scanners are not very cheap to buy because they're like 30,000 or even higher.

Fabian Frei

Yeah, yeah, yeah, exactly. So an impression material is very cheap. And the scanner list price is roughly 55,000 Swiss francs for the newest trios model. So the patient can't really choose because if the dentist doesn't have a scanner, there is no choice. And how does it change the price of the of the service? It doesn't really change it, because taking an impression is also a service. And it has a price. So when they use impression material or whether they use the scanner, it's the same. Impression taking is a service that is defined and it's charged.

The reason we want we would like our dentists to, of course, use the scanners. But you know you can always say yeah, because we want to save costs. That's definitely something that you save, but only very long term because I mean the device is so expensive. You need to do start thousands of impressions. And it's not like it a normal a normal dental office, just like 13 crowns a month. So if you have an all like, you can look that up online as well to get more

accurate numbers, but it's like 13 to 15 crowns, so you need to use a scanner for a long time. Long, long, long time because you before you have cost savings. The main benefits of scanners scanner are actually that Data is stored safely, and you know you have a quality assurance tool. Because it's digital, it's much better for the patient if the dentist uses scanner correctly, softly. If he starts, you know, scraping in your mouth with. And it's not such a pleasant experience, but if he knows how to use a scanner, it's really nice. You don't have to. Gagging or the, you know some. Some people really can't deal with impression material.

Bolliger Martin (bollima2)

Like they are allergic to it?

Fabian Frei

And it's quick. No, no, no. Some are allergic even, but very, very, very few. But it's usually, you know, you press it in and then the IT flows into your throat and then when you lie there, it's like it's very unpleasant, especially for children.

Fabian Frei

Have you had braces?

Bolliger Martin (bollima2)

Yes, yes, I had also this material which was like with berries or something.

Fabian Frei

Yeah, exactly. Well, you know, it's unpleasant. It's unpleasant in comparison to a scam, but in the whole procedure, whatever you do, it's not the most unpleasant thing.

Bolliger Martin (bollima2)

Yeah, but like you need to send them the impression physically to the laboratory?

Fabian Frei

Yes. Though it's time that you save it's you save time, you're faster. You have fewer sources of error because somebody might drop the impression. Might make a mistake when doing the cast. But the really, really big benefit is actually the digital capabilities. Like you can do treatment simulations. You can show a patient how he would look. You can simulate tooth movement and so on. That's the big benefit.

Bolliger Martin (bollima2)

And like uh, it's also that with I heard that the accuracy is better with the scanners or what is your view there that was from the interview of the 3D company and they argument was it's also less errors in the in the taking.

Fabian Frei

Yes, I agree. Yeah, high accuracy. But you know the accuracy topic is an interesting one. There's a lot of research about this which says that scanners are marginally more accurate than impressions So it's not like hugely different, but they are more accurate. It's much easier for the lab to work with the scan. That's why maybe a printing company will say that right, because

they need to have a digital file. And then what? The scanner companies argue with is you have less redoes and the redo is exactly when a crown doesn't fit and you can't use it. You need to do it again, right? But that's not statistically captured by the clinics. So no, nobody. No, it's not locked. It's not like the ERP systems of the clinics, they don't lock these events. So I think nobody really knows, including the scanning companies, what is actually the redo rate they might have done individual studies for a certain amount of time where they can say it's roughly 5 to 6%. But if I go to a dentist and say you will have less redoes, he will tell me about, you know have almost no redoes or non then. So it's a benefit, definitely, but does it work to convince dentists to use the scanner. I am not 100% sure.

Bolliger Martin (bollima2)

Because the redoes are on the charge of the laboratory which loses time, right? Because the dentist says, hey, the crown is not fitting or what is there the relationship?

Fabian Frei

I actually don't know this, but I think you might be right. I think it's like an order you know and if your order is not fulfilled. In obligatory law. Well you need to redeliver the service. So they say it doesn't fit and the lab would just say, well, OK, I'm gonna redo it and I'm not going to charge you for it because it's my mistake. But I don't know this exactly.

Bolliger Martin (bollima2)

Because that would be interesting, or if the dentist then would decide let's say in the far future it would be possible to produce inhouse. And then he has no guarantee if something with the printer is not accurate. He has there, the risk by himself that that he needs to redo the work. And probably there could be also a sign of the dentist that is not willing to change because he has kind of an insurance that he will get the crew crown how he needs it. And at the first time.

Fabian Frei

Yeah. Good point. Good point. It's a negative incentive to actually do it in house, yeah.

Bolliger Martin (bollima2)

Probably question like do your employees in your company have like trainings to new methods or technologies or is there some events where there are new technologies presented?

Fabian Frei

Yeah. So, every dentist in Switzerland has to do 50 hours of additional education per year. They are required to do this. That's by themselves, so each dentist has to do this. They have to prove it. So, they can go to events you know of. They could go to an event where somebody talks about new technologies, and they would get 2 hours for this. But they need to do 50 so it's self-administered, we offer certain trainings as well ourselves. We introduce new technologies in, in regular dentist meetings. And we have an Academy. Where we have certain topics that we focus on and and and people can join us and learn there. That's also provided by our Colosseum Dental Group, which is basically above the Swiss Smile group. They are owning this, so it's bigger, bigger organization. So yeah, we do introduce, and we do talk about these topics. I'm introducing some myself at the moment. But yeah, so I would go to clinics, I would introduce it if I have need for support clinically, I take a dentist with me or I take somebody from the supplier with me. We do introduce new technologies.

Bolliger Martin (bollima2)

And yeah, that's probably the one of the last questions. Like, yeah, where do you see, do you see a lot of change in the next five years going on through Additive Manufacturing?

Fabian Frei

I mean, the last time I dealt with this topic was actually about three years ago when I used to work for Straumann Group. And I was trying to introduce uh. Prosthetics. Like uh, we discussed now to the dental offices and In three years, almost nothing has changed in the clinics. I'm talking about the clinics. The lab landscape, I think has evolved. Gotten more automated, but not huge according to me. I mean, three years ago they already had meaning stations. They already had, like almost fully automated like. And manufacturing workflows. So, the only technology that that came on top was sintering laser sintering, where you can basically. Not 3D print, but no 3D print metal. Yes, they are able to 3D print metal. That's a new technology that was introduced. It's a bit cheaper. Then to middle metal frameworks. But not a huge change if you ask me. The thing is if you think about it. Do you really want to do crowns? That's when your tooth is already broken. Well, I think at you know it's going more and more into avoiding that you lose a tooth or that you have a cavity or that you have to think so. Also look at us young generations. And I mean, you were probably 10 years younger than me. When's the last time you had a feeling?

Bolliger Martin (bollima2)

Yeah, that's true. So far, I don't have any.

Fabian Frei

In the long, long term. You see, so you see more that like there's so much going on in hygiene. Yeah, it's going to be. Yeah, it's going to be aesthetics. You know it's going to be like young guys or young, young women. They are going to be like, OK, my teeth are, I take care of them. I have no cavities, but I would like them to be a bit straighter. So, I'm going to go to the dentist to get clear liners. I'm going to go to dentist to get the widening. I'm going to go to the dentist to. Take care of my teeth. It's more consumer focused. I think it's going to be more consumer focused. The lab will just be, you know, in my point of view, they will still be fixing. They will be fixing things. But if you fix less and less what's going to happen with this market, it becomes smaller and smaller and smaller so. So, I wouldn't want to work in the laboratory space. Yeah, the future is not there in my point of view.

Bolliger Martin (bollima2)

OK, but what to discuss clear aligner shortly? Question what are these? How does it work? I never get like what it's exactly doing.

Fabian Frei

So it is and what's the topic device at? Sounds funny that is invisible. And it uses to say it uses the same principles of orthodontics. It puts pressure on teeth to move them. But instead of having it fixed in your mouth, you have a removable device. You still must wear it for 22 hours a day. It applies constant pressure and then you change the aligner and each aligner, has shifted your teeth a little little bit exactly how you want to. Because if you move teeth too fast, you lose bone. And if you lose bone, you lose your tooth in the end. Ultimately, that's the worst. Or your roots become smaller. Your tooth roots become smaller. So basically, it's invisible. It's much more comfortable. It's even for Grown Ups that want to do small changes. You know, you don't

have to be ashamed that you go to work, and you have the metal mouth. So it's new orthodontic device. While it's not new. Align came to the market 15 years something like that, but now it's ubiquitous.

Bolliger Martin (bollima2)

But is it so effective like? Because you need several of them, right? Until you have it in the right positions.

Fabian Frei

Yeah you change them every two weeks. So, depending on how much you need to move. You have more, and of course you can't do all the movements either. So that's the limitation. You know if you have like. Some people have a very narrow pallet. You can't like expand the palette by this much. With clear aligners, it's basically impossible because the metal at the plastic doesn't have the strength. But for like look at your own teeth's or I have a gap here. I went to orthodontic treatment. I have a gap here which develops because usually after orthodontic treatments, you still have changes. So in 10 years you might, your teeth might look will look different than now, even with retainers, and what you can then do you can say OK. I'm going to do another ortho treatment, but this time with clear aligners and it will be done in six months to 12 months. So, it's also for refinements. Of your current smile.

Bolliger Martin (bollima2)

Have you ever heard of a laboratory of, of you which is delivering that started to integrate Additive Manufacturing processes?

Fabian Frei

No but you know that could be because I'm not so focused on this because as I described to you, in Switzerland and not just me. There is not this need really to demand for this. The Crown just has to be beautiful, and it has to see be seeded easily. That's it how it's produced.

Bolliger Martin (bollima2)

Yeah, I see it. It's also linked to this law. I think or like now I get the impression that this is also a little bit barrier there to, to incentives to reduce the cost because as you said like the dentist gets more suspicious when the cost drops so much, even if probably the new technology would exactly allow this. And probably this is also the reason why it's could still take a little bit longer in the dentistry than in other sectors where it's already quite far with integrating additive.

Bolliger Martin (bollima2)

But yeah, it was really. I get. So a lot of new insights which I didn't saw before was very interesting. I don't know if you have questions from your side so far because you said you're also quite interested in the topic itself.

Fabian Frei

Yeah, I wanted to a little bit find out talking to you. You know whether there is something new coming that you might know or have heard of and I mean, there isn't, right?

Bolliger Martin

The thing it's interesting. In the literature there are some, some who already said that it's possible to 3D print that you call your crown so far. But what I heard of the company I interviewed so far was like, it's also not their focus. First of all, crowns. They're more on the liner side where they vary for in progressing that they can 3D print these aligners.

Fabian Frei

But this would be very interesting.

Bolliger Martin (bollima2)

They are there. They are quite like as far as I heard, they are really trying to progress there further because like as you said, if you need them every two weeks, that's of course a very interesting if you can print them.

Bolliger Martin (bollima2)

And I think they're trying to make progresses. Unfortunately, I just realized this now that the aligners are more interesting than the tooth crowns. I didn't know this in the beginning, but this was now shown with that company. He mentioned that they are setting the focus there and they're making progress. And they're also working together with dentists to get feedback to improvement. But one interesting point probably also from you for you. What I get an insight is that the intraoral scanners are the driving force behind 3D printing. So the more they will be used by dentist and they can progress them, the more accurate will also be the printing in the printing device itself, together with the software. And they say that's like the driving force and the more accurate and better the scanners get the more possibilities they will have in the printing system of the 3D printer. To really be more precise and more accurate, because today he argued that the more accurate the scanner the, the, the better the software and the data is, the better the printer can use it and print it perfectly.

Fabian Frei

Makes sense. Makes sense. OK, yeah, maybe as the next topic for your master thesis, you can look into the aligner topic because the problem with aligners and this, that's why it would be a huge game changer. You know how aligners are manufactured at the moment. Do you know this? So basically, the patient comes in and impression is taken of his teeth, a digital impression. And then this impression is sent to the aligner company. The aligner company creates a digital model which basically. And takes the current state and the end state, and in between it just creates a model for how the teeth need to change. So, let's say they have 20 models and then they print these models of your teeth. And only in the end they use a plastic sheet and thermoform the aligner over that model. So, you have to imagine you have to, you have to print. Let's say you have 20 steps.

That means 20 upper 20 lower printed. Thermoformed cut out and you know the edges have to be, you know, nicely polished. Some companies do that fully automated, but imagine now you must do 200 aligners, that means $200 * 40$. That's a huge amount of room and space that you need. And if you could print it instead of having to like to print the aligner instead of having to print the model. You would save, but you would change the whole game, you would basically the production facilities of a line in it. They have one in Poland which is like 80,000 square meters in Mexico, which is huge. Best Smile produces their own. They have a big you would not need that. And it would be a huge if be game changer. So interesting, because then everybody could print their own aligners with relatively low space requirements and. Yeah, probably faster.

Bolliger Martin (bollima2)

And you could even like when you say every two weeks you could process or program it, that it's always printing at the right time for the right customer.

Fabian Frei

Yes, yes you, now you have to print A at least half of it in the beginning, because otherwise it makes no sense to run the machine and it gets super complicated to align patient with the box that you get. It this would be a this would be immense. This would change the landscape.

Bolliger Martin (bollima2)

I think they are on a good way there, so could probably be interesting for your company.

Appendix F: Interview with Olivier Jaren and Philip Aymonier

Interview Partner:	Olivier Jaren / Philip Aymonier
Role	Dentist and Operation Manager / Dental Technician and Lab Manager
Company	Adent Group
Interview Type	Dentist Chain
Date/Time:	22.04.2022 / 11:00
Interview Duration	41 Minutes 26 Seconds
Interview Language	English
Format	Online

Bolliger Martin (bollima2)

First of all, as an introduction I would introduce myself and later to give you the opportunity to tell me shortly a little bit of about your professional background. So my name is Martin Bolliger. I'm in my last semester of my bachelor's in International Management and I choose the topic centralization or decentralization with the technology of Additive Manufacturing. And therefore, I choose the industry of the dentistry and more specially on the production of tooth crowns. And the questions will be regarding process management but also quality, cost management and innovation management, because I want to find out along the supply chain which barriers, they're still exist that the Additive Manufacturing can be introduced on a larger scale basis. With that said, I would give the word to you that you could shortly introduce yourself and tell me a little bit about your personal and professional background.

Olivier Jaren

OK, so I started already, so I'm the dentist and now I'm an operation manager and in my task I have the coordination of the lab activity. So I work closely with Philip with the lab manager in the main lab, he is very experimented in the 3D and milling.

Philip Aymonier

So I'm my name is Philippe Aymonier. I'm dental technician. I am the lab manager for the group of Adent for all the frenchspeaking part and I have different mission. My main mission is the quality to provide good quality in the right time and in parallel, but it's becoming the main mission to keep up to date and to have the best system on the market and I had the mission to digitalize all clinic in the lab work. So we had to switch from the classical work to the digital way .Milling and printing is now the main task

Bolliger Martin (bollima2)

OK. So that would probably lead me to my first question. What is your current procedure when a customer comes in and the dentist realizes he needs a new dental crown?

Philip Aymonier

So it it depends of the equipment that the dentists have. In reality to have a perfect workflow, you have to understand that there is a dense side and there is a lab side and we have a kind of hybrid system. So if the dentists don't have the equipment. To work in digital way, they can send us the normal cases with the classic impression and we will do the plaster, do to the scan, the digital design, the validation, the milling or the printing depend of the cases and send it back to him. The dentist is equipped with the dental camera. He scan with the intraoral scanner. He

will scan. He will send us the file with all the order and we will do the design validation. If it's needed, correction if needed and we will decide to print or to mill. And after we will finish by hand and we will send him back.

Bolliger Martin (bollima2)

And the decision to print or to mill is in the laboratory taken?

Philip Aymonier

Yeah, most of the time we are the support of toys for the dentist because he don't know all the materials. It's not his job. And sometimes you have an idea, but we will do proposal depending of the shade of the case we have to do and the size of the case we have to do and this is the main point really a big full arch to do you will not use the same material like for a small arch. We know this. Most of the times the limit to change the material is 3 elements, like a breach of three elements.

Zirconia. In milling we use IMAX, it's lythium disilicate, its close to the glas, zirconia. We mill it in the soft way. Not in the hard way because it's too hard. And you can find all the all the other properties of this material on Internet it's close to a 420 in hardness So it's close to the teeth. In printed material we use the mostly plastic, syntheron for big material. We use the classic plastic for the model. We use a lot of material and for milling we can use close to everything if we want, but we don't use everything. We use composite EMAX and zirconia mostly

Bolliger Martin (bollima2)

And what is the duration like? How long does it take from the scanning which you receive in the laboratory, till you will have the crown and send the package to the dentist?

Philip Aymonier

So we have the delivery time, we have to make the job, it's two days for the small element. We can already finish, but in this time it's included all the preparation time cooking time. Because you have to to frame in the in the in the oven. So there is a lot of step that we have to do by end. But if you consider all this time of step you will have between 15 for one element. For single code we will have 15 minute of design. You can count really at the beginning 10 between 10 and 15 minute to open the scan to check the scan to check the order, this takes time. Maybe to contact dentist too, to ask more information. 15 minute of design after we have a control between 5 and 10 minutes for each element, we send it to the machine to put in the machine. It takes time between 10 and 15 minute again and after a milling time for one element depending of the material it between 8:00 and 25 minutes for one single crown. After this we have to cut put it out from the machine to cut from the support and For the EMAX, we call this the crystallization. We have to put it in the oven and we will have 30 minutes of cook around 800 degrees and it will have the shape because it come out purple. And after this the technician will start only know he will start to work on it and to put the stains to have the shape you want to finish and after we can send it. For the zirconia we call this it's the same, but it's called syntherization. And it take 8 hours. Now, there is new Zirconia which need between 15 minutes and 12 hours for the big cases.

Bolliger Martin

So you mentioned already printing. So do you have already parts which you use Additive Manufacturing or how you meant that you print?

Philip Aymonier

To print we really print not the same stuff. We will print mostly for the try-in really just for instant try in. If you are speaking about tooth or the teeth, we will print like we make a design for a big cases for interior cases we don't know the aesthetic we want to have a confirmation with the patient. We will print it because it cost not so much time and not so much money and we know that it go to the trash after. So we just fast print. We give it to the to the dentist. He makes the try in the mouth and that's it. After we finish with a good material, for the rest of the of the teeth. We don't print anymore. Just some provisorial but we prefer to mill it. So we will print the models when we need it work models, splint. We can print the splints with the transparent plastic material.

Philip Aymonier

This kind of work we are printing. Two very different.

Bolliger Martin (bollima2)

Like I heard already that there they are on it to have a 3D printed crowns with zirconia. Like they are on it to develop that but like. Where do would you see the main difference like?

Philip Aymonier

I think the future is in the printing not the milling. Milling we made the turn. We know everything about milling. We may improve it, not so much, we have 5 axis machine, we have disks we have blocks, we have a lot of material. What can we do more? Not so much In my opinion. But printing for the dental it's we are in the beginning because there is still a big difference in between the industry, big industry, what they are printing and what we are using we use maybe I don't know 30% of what what we can do. the problem at the moment is that we don't have big series. Each case is unique. So even for the zirconia. They are making a lot of settings to have the occurrences they want and the reproducibility of this. So in the industry they will do 200,000 of the same part they are using for the watches they are printing already using zirconia. I have a friend who is in in this kind of work and he will tell me the feedback because about it in the school and he will tell me the accuracy and the consistence of the material after this is very important at the moment. In the dental we can't use it because it's printing very opaque material. There is no transparency. So we can't choose it at the moment. But but for all the plastic material we will use it and I think it's the future because if you take the shade in the mouth and you can reproduce the shade with a printer, if we can print different colours. Then we will print. But the printing material, it's not ready for the dental. It's not the same material.

Olivier Jaren

But the point is, this is the material itself and you need to have a Class 2 material for that. It is different from industry, so you need to have the right material safe material. So there is many progress on this point also.

Bolliger Martin (bollima2)

My question there is like how the collaboration with the dentist and this you can elaborate pretty good because as I understand that in your company the laboratory is in house so you're the responsible. So how is the collaboration between the dentists also for improvement of quality.

Philip Aymonier

So it's very easy to see we have close contact for each case. Its really a service that we are providing and to have the quality because we are making each case unique. For most of the cases, we have a call with them. We are very close and for each case, we are sending, we are the only one to do this for each cases. We are designing even for small ones. Our lab designer or dental technician first, they're not from outside. The technicians that will provide formation on the digital. They make screenshot. They made the video and for each cases they send it back to the dentist immediately for validation. OK, so this is the kind of where we are working with dentist like that and if there is something wrong, the dentist immediately have to to tell us that there is something wrong. We have to change the setting, we have to . Like I told you again it's each case is unique. You you can't know. So we have really a close collaboration with immediate feedback

Bolliger Martin (bollima2)

So he will see on the computer the model and then he can say I want to have there an adjustment or this is not fitting or.

Philip Aymonier

I can transfer to you immediately. I will remove the patient and you will. You will have what we send to the dentist. So you will understand. And even more he always can connect to our computer with Teamviewer. So he see online these cases on the screen and can check there

Olivier Jaren

I'm gonna have a testimony. With the 3D trying because I use it myself and it's really another value. Because you can verify that's not the right color, of course, but the shape, the contact occlusion, you can check the perfect fitting, it is wonderful, honestly, especially for big structure like Philip said. For full arch or very aesthetic. It's a really something new and fantastic.

Bolliger Martin (bollima2)

See, so it really facilitates also your work as a dentist because you have way better imagination on the computer then?

Olivier Jaren

Yes absolutely. And even I can correct grain something and rescan. And the resend to Philip and he modifies this one. I think we are not so many labs to have this facility now.

Bolliger Martin (bollima2)

Yeah, but like the when you scan this, this scanners or they, how is there with the accuracy to is it happening or that you sometimes need to rescan your custom the customers mouth or is it always very accurate already the scan? And they're so you just scan once and then it's done.

Philip Aymonier

We can see this. The first step is that the calibration have to be done each week. Each week, so we take care too that it's done in the clinic when they have a scanner. So like in the industry, they have a paper of who made it always made it because there is the accurate Calibration. But

there is the colour of calibration because you know most of the scans they have the colour. The one we have in the Adent group, they all have the colour. So they have to do this calibration each week.

We see if there is trouble immediately in the lab and we if we don't see, we see it immediately in the mouth because it will not fit. The Crown will not fit, so they will call us and say, hey, it's not going in the mouth.

Bolliger Martin (bollima2)

And you said like in the process you make quality checks.

How do they happen? You see, you can put it in a machine to check on consistency and that it's stable. Or how do you make the quality checks?

Philip Aymonier

So about the material you mean or about the quality?

Bolliger Martin (bollima2)

Like the material.

Philip Aymonier

So for the big cases were using the light for Zirconia just after this interrelation to check if there is some breaking side. And for normal cases, we put it in the light too, but it's not so how to say there is there is not so many problems with this the material we are using right now. So most of the time you see it with the eyes immediately there is something wrong and after you check the fitting on the model because we still print the model we can do for the single element we don't need the print model because we trust in the occurrences. But if we have like some doubt we can print the model that we control it. Why is it with the eyes and with the binocular? I think it's crossed 10. Of course, then of the biggest. So yeah, it's already huge and it's by, by, by with the eyes and with the competences technician. This makes a difference if you have a good technician, you will have a good control.

Olivier Jaren

The biggest challenge is if its full arch, where we could have some problem of accuracy in, you know, for us you can have a discrepancy between the right and the left because it's a really a big way. So we need to be careful about this.

Olivier Jaren

For single elements, but for full arch we need to be very careful.

Bolliger Martin (bollima2)

So as I understand that you make so many checks, you have not often the case that the crown is not fitting like it's not needed to be sent back often to the laboratory again.

Philip Aymonier

No, what most of the time when something like that happened, it's not coming from the scan or from the finishing. It's coming from the preparation of the dentist at the begin. Or what can happen is for aesthetic cases, sometimes we have a difference on the shade and we have to

adjust. What we can provide here within Adent group when we have a good contact with our patient and they come in the lab. It's a service that we are providing for the aesthetic cases, and we do it with the patient on the side we go to the clinic or the patient is coming to the lab and we do this, but we don't have so much problem of the material.

What is your opinion towards the Additive Manufacturing and the new possibilities in the future? Like where do you see this going further because you also said mentioned that it's will be the future the printing.

Philip Aymonier

Yeah, for for me, I mean actually we are making between, I don't know. Depend of the period, but the kind of work in dentistry you have to understand that the treatment that they are providing to the patient, they are changing to. Not all the dentist are providing the same treatment for the same cases, so depending of the cases there is an evolution to go for the full digital absolutely just at the time that they are acquiring the new equipment. First, because it has a cost, but of course it is the future and I think soon it will be 80% of digital for digital and 20% of the classic Act. At the moment it's 60% classic and 40% for digital. But more and more we go to the full digital and about printing. I absolutely trust in the printing because It's not about what we can print, it's about what we cannot print and we can print everything more and more. It's just some colour settings stuff. So I think this is really the future.

Bolliger Martin (bollima2)

And what do you Mr JAREN? What do you think? How do you see this in the future from the dentist side?

Olivier Jaren

In my opinion. I think we have many new match our own now with no metal. And yes, I share the opinion of Philip. I think that the future is more imprinting. Even with small printer, for smaller surgery like in House production office production, there is more than more provisional currently.

Olivier Jaren

We can also drop some steps so it's less time for the patients with more accuracy. We are maybe Philip, you can speak about innovation with a full digital denture. This is a hot topic now.

Philip Aymonier

Yes, just about to do is at the moment we are using the two together. We are some for some cases we print the part like for the for the digital denture we are printing the part in pink and we are milling the teeth in white and we glue it together and we pretty good results so.

Bolliger Martin (bollima2)

The dentist. Do you have a or their courses or education where they inform you yearly about the new technologies? Also probably for the dentist that they more get to know these new technologies because I mean you're in a big company but probably smaller dentists don't get in contact with Additive Manufacturing like how is there the procedure for your staff?

Olivier Jaren

Yes, we have a good training program and now we are gonna to create some hybrid program with clinicians and labs. That's very interesting to understand each part. And so this is a we were in netherlands with big loud because we belongs to an European group. And we are organizing this kind of meeting. Internally I mean.

Bolliger Martin (bollima2)

But as I understand, is your laboratory also with external dentist working together or like probably to understand the live aboard the setup of the Adent group?

Philip Aymonier

So the total of the of the lab, we have some lab in the in the German speaking part. But I take care of them in a way, but I'm not the manager for them. And in the French speaking part, we have one lab in Yverdon, one lab in Neuchatel. Tell one lab in Geneve and the main lab is in Renens. All the small labs are making a kind of dental technique. It's called the removable because we need to contact more. More physical presence to do this cases adjustment and so on. But all the fixed part is going to Renens here and it's here where we have all the machines.

Bolliger Martin (bollima2)

So you are Printing or preparing the pieces at the centralized place and then for further preparation in these specialized laboratories it will be treated further.

Philip Aymonier

Yes.

Bolliger Martin (bollima2)

And now my question is, the more you introduce or digitalize has this also an influence of the costs you for your client or like the production, the cost of the Crown itself?

Philip Aymonier

Yes and no. Because uh, in reality, it moved the cost before the cost was in the consumable and on the time of work. So on the human. But it moved to the machine and to the license and to the update. So it changed the way, but not so much. But no, we feel that it will go down little by little, but at the same time, always the same depend of the expectation of the dentist and of the patient's. Because still, even if you are printing, if we are meeting, if they have an expectation, very aesthetic, it will need to spend a lot of time to finish it. And for this you have to find a good technician and a good technician cost money so. Still, we have cost. It's not. It's moving a bit, but not so much. And uh, always the same. If you want to use good material, there's good material has a price

Bolliger Martin (bollima2)

OK. What? What, what do we talk there about the range like for a single crown?

Philip Aymonier

We are charging for a a single crown in the IMAX or the chronia between 500 Swiss francs to 650 Swiss francs, depending of the cases for a single crown. For a nonlinear or an overlay we are around, I think in full digital workflow. Here you will feel it because for the full digital workflow we are 240 Swiss fans because we are not printing the model. And if we have to print the model we will be around 340 so here you have a huge difference because. It's not about

material or something like that, just we remove a part of the work we are not doing the model anymore, so we will not charge them.

Olivier Jaren

And you have only one way that way less for digital because delivery takes time also and have some cost. If you mill mutants or for Zurich, of course you need to send the packet. But if you work in full digital. You only have one away.

Bolliger Martin (bollima2)

In the future, the Additive Manufacturing, so it has a positive effect on the cost structure. If we talk of fully digitalized solutions.

Philip Aymonier

Yeah, yeah, of course it will have it. It's about the volume. It's like for the industry, like I told you, for the industry, it's about the volume, how we will manage our volume because each single case it's unique. It will be about with the printing it will be about the shade. The shade mainly was the shade, so he if we have a huge volume coming in one print we can print 300 crones on the same shade or around the same shade. Then we would just the cost because we will have less time. We'll do it at the same time, we will use less material. But now we cannot do this. But it will come for sure it will come.

Bolliger Martin (bollima2)

And probably how to further understand how was the integration of now that you have partly Additive Manufacturing? How did this work in your company? How was this to implement like problem? What were the challenges to implement this together? Also decide probably what the dentist thought about the new technology, how you manage that.

Philip Aymonier

It's education formation communication demo demonstration to prove that it work if you do this it's huge work. But in reality you have to think about this before to start. I will give you an example and it be the same. We managed to remove all the metal from our denture. During more than one year, I made a lot of test. How to implement it in our clinic. How to communicate how to do it? I made some test by myself during one year. But after when we start and I say OK, we are ready, we will do, we will go on this way. In one week in one week for all the clinic for all the lab we changed and we switched, with no discussion. It is really about to go forward to do this step. But to do this step if before everything is working good, you can do it easily. The dentist will trust you. It's about trust like I told you, I mentioned you all the key points.

Olivier Jaren

And a form of the clinic side, we invest a lot in into our scanner. Each clinic has A at least one summer at three. So we have convinced also the dentist to change to make digital impression prior to Analogic or old fashion.

Bolliger Martin (bollima2)

So the probably 1 interesting question is how many tooth crowns you produce per year or like? Or if it's easier to say on a monthly basis or.

Philip Aymonier

On the day basis in our lab, actually each day are going out from the lab between 10 and 50 crowns. Then he goes the period. It's already huge. For Switzerland its huge. And I'm speaking about crown, but it's difficult to make an evaluation of of of this because you can have a series of huge work. If you check I think I made the post on LinkedIn. I had two big cases came in the lab and of course this cases are huge and they will take a lot of time. So, if you have two case like that you hope that you will not have so many crown to do because you take a lot of time to finish.

Bolliger Martin (bollima2)

Otherwise you get to the limit of production.

Philip Aymonier

Yeah, you are too small to take everything. Even if we are big.

Bolliger Martin (bollima2)

Would you see your company as a traditional, modern or innovative company?

Philip Aymonier

I think that we are speaking about digital since so many years. And we did this step, I think five years ago with the digitalization of the clinics and because we had some other stuff to fix and to manage first to have good basis to keep a high-quality standard. This is the main point of the of the Adent clinic. Our fight is to be a high-quality standard. We don't want to do low cost. We don't want to break the price to have customers, to patient and it's not the Idea. So first we'll fix all these points. And since now two years and moreover since December with these new labs. We are absolutely innovative. We are not a following company, we are innovating company and we always keep up to date of what is we are doing and we have the unique chance to be a part of European Dental group. We are we, the main group of dentists and dental lab in Europe. And we have so much knowledge to take from all these other people who are innovative too, that we are of course and in the in the high of the of technology. Just we always wait that everything is working good before to invest.

Bolliger Martin (bollima2)

That makes sense. Yeah, and probably is there also then when you mention close collaboration with 3D printing companies now like are you there in exchange to improve properly also their products that you could in the future integrate it by your own or introduce it? Yes, we have some contact, but it takes time. It takes time to do this kind of of partnership and actually we don't have this time because I'm not a university. I'm here to provide quality to our patients. There's big lab in Holland, mainly in Holland. They are doing this. They are even making the development of the new product with them. Especially for the sessions are making really the conception of this project, but we can't, we will try homes for some partner like OK we can do some tests for you, but it's not our job, it's not our specialty or speciality is to do the teeth of quality for our patients.

Bolliger Martin (bollima2)

But like that what you mentioned in Holland is also part of the Adent group or is that external?

Philip Aymonier

It's a big group who own dental lab in Holland, in Belgium and everywhere in Europe. OK, so we are colleague.

Olivier Jaren

Yeah, it's the mother company.

Bolliger Martin (bollima2)

I had also an interview with a 3D printing company and they also mentioned that they're trying to further progress in the Additive Manufacturing. And as I understand it, also quality certificates?

Philip Aymonier

Yeah. About the medical certification to go in, the mouths are hard to have in Europe.

Olivier Jaren

So true.

Philip Aymonier

I was saying in United States they already use products that we are not able to use here.

Olivier Jaren

Specially in Switzerland, because you have Swiss medics and you have a new medical device regulation which takes place in June and it will change many things because some products could not cross the border with this new regulation. It means that only big company could manages the small began very difficult for them. Other points you can mention regarding additive process. This is a new affiliate regarding ecologic point of view because we had some hints, some raisins, some debris. To manage because you use the he's well call many dentals products and how to manage this after. It's it. I think it's a good point to to mention with Additive Manufacturing.

Philip Aymonier

Yeah, absolutely. Ecological site. It's absolutely a point that I don't know if you already check about it, but it can be very interesting because we have a lot of concerns for the product we are using, we need a mask. We need gloves, we need glasses. And we can't throw it away where we want. We can put it in the in the trash. So it means that it's not so good products at the moment.

Philip Aymonier

I'm just saying that when we were working in the in the classic way, we were using mostly the plaster

Philip Aymonier

It's store so you can reuse it. Not so problem here with this kind of of productwe are using plastic. This is the main point.

Philip Aymonier

No, not really

Olivier Jaren

No, no, that's right.

Bolliger Martin (bollima2)

So you hope that you don't need to print in plastic anymore.

Philip Aymonier

Absolutely.

Olivier Jaren

Yeah, it's just enable, yeah.

Philip Aymonier

Or plastics that we can reuse or something like that.

Bolliger Martin (bollima2)

But do you think like when you say you print still the model to test it afterwards? If it's fitting you, do you imagine that there will also be the possibility that the software will do this and will be so accurate that you don't need to print it anymore in a plastic way?

Philip Aymonier

Yeah, of course. Yeah, of course we are already doing it for the single Crown.

Bolliger Martin (bollima2)

There you have no model anymore.

Philip Aymonier

Yeah, yeah, it's about the quality of the software design software.

Appendix G: Interview with Manfred Goth

Interview Partner:	Manfred Goth
Role	General Manager
Company	Caddent
Interview Type	3D Printing Center for Dental Laboratories
Date/Time:	22.04.2022 / 15:30
Interview Duration	34 Minutes 47 Seconds
Interview Language	German
Format	Online

Manfred Goth

Also mein persönlicher Business Background, ich bin Zahntechniker auch mit Meisterbrief hab hinter der Werkbank gesessen und klassisch Zahntechnik gemacht. Hab aber auch schon Labore geleitet. Ich bin dann irgendwann in den Vertrieb gegangen, hab irgendwann noch Betriebswirt nachgeholt. Ich bin also Zahntechnikermeister und Betriebswirt. Und bin jetzt seit fast 30 Jahren in der Dentalindustrie tätig gewesen. Im Bereich Marketing Vertrieb Business Development. Auch vom Außendienst, also wirklich von der Pike auf bis auch führende Position auch schon Verantwortung für Dach Region gehabt und bin jetzt seit 2 Jahren hier im Unternehmen. Mit dem Ziel, dem Inhaber es ermöglichen, dass er sich zurückziehen kann. Ich soll die Nachwuchs Führungskräfte ausbilden und das ganze Unternehmen zukunftsfähig machen. Sowohl innerhalb Dental, aber auch mit dem, was wir können überlegen, ob wir nicht auch außerhalb Dental damit Geld verdienen können.

Bolliger Martin (bollima2)

Okay, das würde mich vielleicht zu meiner ersten Frage direkt leiten ist wenn ein Kunde bei Ihnen oder Zahnarzt eine Zahnkrone bestellt, wie ist das jetztige Verfahren? Wie gehen Sie da vor?

Manfred Goth

Das Verfahren ist so, dass wir einen Zahnarzt direkt gar nicht beliefern. Das hat folgenden philosophischen Hintergrund. Wir als Caddent verstehen uns als Partner der Zahntechniker. Und was auch immer wir herstellen, muss noch ein Zahntechniker Hand anlegen. Das ist die Firmenphilosophie, weil wir den Zahntechnikern ermöglichen wollen Geld zu verdienen. Sprich wir machen für den Zahntechniker, das mit Maschinen, was man einfach kostengünstiger machen kann, als wenn es der Zahntechniker in seinem Labor selber macht. Aber die Grundphilosophie der Caddent. Es muss immer ein Zahntechniker Hand anlegen. Es kann natürlich einen Zahnarzt und Praxislabor haben ok für den arbeiten wir auch. Genauso wie für das gewerbliche Labor. Aber keinen Zahnarzt von uns jetzt beauftragen, damals herzustellen. Wir wären in der Lage, ist zu können. Aber wie gesagt die Philosophie Caddent sagt es muss immer ein Zahntechniker noch Hand anlegen und aus dem, was wir herstellen, final Zahnersatz fertigen.

Bolliger Martin (bollima2)

Okay das heißt jetzt zu den Zusammenhang Sie drucken ein Teil der Krone auch mittels additiver Fertigung oder?

Manfred Goth

Also wir haben sowohl die subtraktive Fertigung als auch die additive Fertigung im Haus. Der Schwerpunkt ist die additive Fertigung. Wo wir, wie gesagt, Teil gerüstet Teile von Zahnersatz per additiver Fertigung herstellen aus Kobaltchrom, aus Titan. Wir können auch Edelmetalllegierung drucken. Wie haben seit Januar einen Keramikdrucker im Haus und können auch Kunststoff drucken.

Bolliger Martin (bollima2)

Okay, und das heißt danach, senden Sie das, Produkt entweder an das Labor oder wie sie gesagt haben, je nachdem auch Zahnarzt, der selbst noch ein integriertes Labor hat.

Manfred Goth

Genau das sind quasi Halbzeug oder Halbfertigprodukte, die wir herstellen und die bekommt dann das Praxislabor oder das gewerbliche Labor und die machen daraus fertigen Zahnersatz.

Bolliger Martin (bollima2)

OK und der Eingang ist das jeweils, das sie arbeiten sie da mit dem Abdruck, welcher physisch reinkommt oder auch schon mit diesem Oralscanners

Manfred Goth

Sowohl als auch, also der Zahnarzt kann vom Intraoral Scanner seine Daten an uns schicken. Das gewerbliche Labor kann seine Modelle selber einscannen und uns die Daten schicken. Es gibt aber immer noch Kunden, die uns tatsächlich Gipsodelle oder auch Abformungen schicken. Die die Modelle draus machen und dann einscannen. Also wir sind ja sehr breit aufgestellt. Wir können die ganze Prozesskette von Anfang bis Ende abbilden und der Kunde kann aber selber entscheiden, welchen Teil der Prozesskette möchte er selber machen und welchen überlässt er uns.

Bolliger Martin (bollima2)

Okay, okay und was sind wir? Sind da ihre bisherigen Erfahrungen mit der additiven Fertigung? Wenn Sie das schon im Einsatz haben?

Manfred Goth

Also wir machen jetzt seit 16 Jahren. Da sind wir mit einer der Etabliertesten im Unternehmen. Wir verarbeiten Titan. Wir verarbeiten Kobalt Chrom im Laser-melting Verfahren. Kunststoff haben wir sowohl stereolithografisch als auch als Filament Drucker im Haus. Edelmetall drucken wir vergleichbar wie Kobalt, Chrom oder Titan auch im Laser Melting verfahren. Dieses ganz spezielle Verfahren, das haben wir auch selber entwickelt. Seit 2 Monaten lernen wir Keramik zu drucken.

Bolliger Martin (bollima2)

Also Sie sind Vorreiter in der in der Technologie? Ich sehe, dass die Firma schon früh angefangen hat mit additiver Fertigung

Manfred Goth

Ich denke das kann man so sagen wir sind. Wir sind mit die ersten gewesen also vor zirka 16 Jahren hat man hier angefangen, additiv zu fertigen. Und die Größenordnung, in der wir uns bewegen, sind wir, glaube ich, auch die Größten, die es gibt in Europa

In ihrem Druckzentrum was sind da die Anzahl Kronen zum Beispiel, wo sie am Tag oder pro Monat drucken, wissen Sie das ungefähr?

Manfred Goth

Muss ich kurz überschlagen? Ich schätze, dass wir auf mittlerweile ja irgendwo 250'000 – 300'000 Bauteile komme pro Jahr, die wir additiv fertigen. Zwischen 800 und 1'000 pro Tag. Wir arbeiten 6 Tage in der Woche das Ganze Jahr durchgängig also, das ist so ungefähr die Hausnummer, in der wir uns bewegen.

Bolliger Martin (bollima2)

Und Sie haben Ihre Produktion, ist zentral und dann liefern sie die Teile oder versenden die Teile oder wie funktioniert genau?

Manfred Goth

Also wir sitzen ja hier in Augsburg, ja, im bayerischen Schwaben. In der Nähe von München und unsere Hauptmärkte sind 50% Deutschland und die anderen 50% teilen sich Frankreich und Italien. Wir haben aber auch Kunden, zum Beispiel in Australien bei uns Teile fertigen lassen auch in der Schweiz, Österreich, Skandinavien. Aber die Hauptmärkte sind Deutschland, Italien, Frankreich. Die Kunden schicken uns die Datensätze in verschiedensten Formen oder wenige auch noch die Modelle wir fertigen und versenden dann jeden Tag die Teile an die Kunden wieder retour.

Bolliger Martin (bollima2)

Okay? Und da die Materialien ich weiß nicht gut, sie haben gesagt, sie sind die. Wie müssen die speziell verpackt werden oder kann man die, dass die nicht irgendwie zerbrechen beim Transport, oder haben sie da einen speziellen Transport oder wie von wie muss man sich das vorstellen?

Manfred Goth

Ja, also, die die Teile, die aus Metall gefertigt werden, die sind schon ziemlich stabil. Keramische Objekte müssen natürlich wie ein rohes Ei behandelt werden, da gibt es entsprechende Verpackungen bei uns. Das funktioniert ganz gut. Wenn mal was passiert, sind wir aber auch sehr kulant und bieten auch Versicherungen an. So dass der Kunde da eigentlich wenig Nachteile daraus hat, außer dass sein Timing aus den Fugen gerät.

Manfred Goth

Vielleicht, dass sie auch so viel Background haben von ganz unten hoch. Was sind Ihrer Ansicht nach die Hauptunterschiede jetzt zu einer Zahnkrone oder Teil der in 3 D Drucker hergestellt wird und in der subtraktiven Fertigung muss? Sehen Sie da irgendwelche Unterschiede? Sehen Sie das Vorteile, Nachteile?

Manfred Goth

Also muss man jetzt die Perspektive betrachten für einen Kunden verhält sich das neutral, der merkt praktisch keinen Unterschied. In der Fertigung gibt es schon einen Unterschied. Ich bin in der additiven Fertigung wesentlich schneller versus Subtraktive Fertigung. Und damit in Summe sind natürlich auch die Fertigungskosten wesentlich günstiger. Es gibt wenige Geometrien die kann man Drucktechnisch nicht herstellen. Es gibt auch die Ideen additiv

fertigen und dann nach Fräsen. Machbar ist technisch alles. Aber nicht in der von uns geforderten Geschwindigkeit und nicht in der Preisspanne, wo wir liefern müssen. Also halt einfach den Vorteil es geht wesentlich schneller. Und ist fertigungstechnisch günstiger. Vom Kunden der sieht keinen Unterschied. Der Zahnarzt merkt das nicht der merkt das überhaupt nicht.

Bolliger Martin (bollima2)

Sehen Sie noch andere Vorteile ich weiß ja auch Material braucht man hier weniger bei der additiven Fertigung. Bei der additiven Fertigung also man kann auch Material sparen oder?

Manfred Goth

Also und somit ist wirkt sich ja dann bei den Herstellkosten aus.

Weil ich ja beim Fräsen, ich hab voll Material. Wo ich vielleicht im besten Fall 80% des Materials verwerten kann. Ja und der Rest ist Müll. Und das hab ich bei der additiven Fertigung überhaupt nicht, da hab ich keinen Müll, da kann ich hundert Prozent Material verwerten. Ich kann immer wieder Material nachgeben, ich hab keinen Ausschuss mit.

Bolliger Martin (bollima2)

Was sind jetzt Ihre bisherigen Erfahrungen mit dem Keramikdrucker? Was zeigt sich bis jetzt

Manfred Goth

Das ist ein sehr spannendes Thema. Weil da muss man auch differenziert betrachten. Innerhalb Dentalmarkt sehen wir dann nur ganz, ganz wenige Anwendungsmöglichkeiten. Wir fokussieren uns da mehr außerhalb Dental in der Medizintechnik und in der Industrie also wir haben ein Paar in den in der Medizintechnik. Wir wollen in absehbarer Zeit Titan Implantate durch keramische Implantate ersetzen. Die man individuell drucken kann. Aber für uns jetzt noch 2-3 Jahre dauern, bis wir soweit sind, weil da der keramische Werkstoff gegenüber dem Titan einfach Vorteile hat. Und Keramik war bis dato so nicht formbar. Sagen wir mal so und in der Industrie sehen wir ein Vorteil. Die Additive Fertigung hat im Wesentlichen 2 Vorteile entweder habe ich hab eine hohe Individualität im Objekt.

Das ist ja bei uns in der Zahntechnik der Fall Wir haben los Nummer 1 jedes Objekt ist anders. Und der zweite Vorteil Ich kann Kleinserien fertigen. Ich kann halt eine kleine Serie von hundert Bauteilen fertigen, wo ich anderswo vielleicht 10'000 oder Hunderttausend herstellen lassen müsste. Das ist somit ein Nebenschauplatz der additiven Fertigung. Dann subtraktive Fertigung vielleicht dann ersetzen, wenn ich wirklich kleinst Serien fertigen muss, also unabhängig vom Rapid Prototyping usw, wo sie eigentlich herkommt.

Bolliger Martin

Vielleicht noch kurz ne Erweiterungsfrage bei den Keramik wo sie gesagt haben, die haben weniger ne Anwendungsoptionen in der Dentalmedizin. Weshalb ist das?

Manfred Goth (bollima2)

Das Betriebsgeheimnis das mag ich nicht verraten. Aus dem Grund, da sehe ich noch als unseren Wettbewerbsvorteil aus dem einfachen Grund viele, die sich gerade auf das Thema stürzen und die Ideen haben, auch in der Dentalwelt Keramiken zu drucken. Jetzt hab ich für mich eine These warum das nicht funktionieren wird, die möchte ich aber nicht preisgeben, vielleicht irre ich mich auch aber zum heutigen Zeitpunkt möchte ich darüber reden

Bolliger Martin (bollima2)

Okay, ja sicher kein Problem. Und dann vielleicht noch ne Frage wie ist die Zusammenarbeit, wenn sie jetzt mit den Druck mit dem Labor und entsprechend ist da eine häufiger Kontakt Austausch, versucht man da auch dann Verbesserungen vorzunehmen und oder wie funktioniert da der Austausch?

Manfred Goth

Ja, der ist sehr wichtig. Die Kunden schicken uns ja einfach ihre Daten rein. Und wenn wir feststellen, können wir so nicht bauen, dann kommunizieren wir natürlich sofort mit dem Kunden. Und nutzen unsere Expertise, wir haben Fachleute, wo wir als Berater zur Verfügung stehen, wenn Kunden Probleme haben, Problemstellungen haben, dann helfen wir denen auch. Wir haben eigenen Kundenservice innerhalb von Deutschland, aber auch für Italien und Frankreich, haben wir italienisch und französisch sprechende Kollegen, um möglichst nah am Kunden dran zu sein. Weil für uns ist das das gleiche Kapital wie die Qualität, Kundennähe, Kundenbeziehung. Für uns ist das genauso wichtig wie die Qualität im Objekt.

Bolliger Martin (bollima2)

Vielleicht zur Qualität noch etwas wie oft erleben Sie das vom Drucker her etwas falsch oder nicht richtig gedruckt wird. Was sind da so die Tendenzen?

Manfred Goth

Also Fehler entstehen eigentlich nur bei der Konstruktion beim Kunden. Das was wir dem Drucker sagen, was er drucken solltest, druckt er. Die Erfahrung haben wir mittlerweile, dass wir wissen, wie wir die Objekte auf der Bauplatte positionieren müssen. Das auch das rauskommt, was wir da eingeben. Das ist die Erfahrung, die wir haben da passiert so gut wie nichts.

Bolliger Martin (bollima2)

Das haben Sie mir eigentlich schon beantwortet, aber ich möchte vielleicht trotzdem noch ein bisschen weiter eingehen. Ist das additive Fertigungsverfahren hat positive Auswirkungen auf die Kosten. Jetzt wie stark sind die oder wo kann man das einordnen?

Manfred Goth

Ja, kann man das einordnen. Wenn wir mal von der Einzelnen Kronen sprechen. Ja auf einer Bauplatte haben 200 Kronen platz. Und mit aktuellen Lasersystemen brauche ich für diese 200 Kronen zwischen 6 und 7 Stunden Bauzeit also auf einem Laser mit einer Maschine Ein so ein Laser kostet 400'000€. Wenn Sie jetzt die vergleichbare Menge Rausfräsen wollten. Bräuchten Sie wahrscheinlich 10 Fräsmaschinen, wo jede hunderttausend Euro kostet? Also so pi mal Daumen bringt mich da nicht genau drauf fest, aber so ungefähr. Weil ich einfach in einer Zeiteinheit? Ein Vielfaches mehr an Menge additiv herstellen kann im Vergleich zum Fräsen. Plus den Ausschuß, den sie beim Fräsen haben. Beim Fräsen habe ich ja noch extremere Anforderungen an die Maschine. Die Maschine ist extremen Anforderungen ausgesetzt die Spindel die da, die diese in ich muss ja irgendwo die Energie auffangen, auch. Wenn ich Span abtragen, bearbeitet, das ist ja viel Energie, die im Einsatz ist, die muss ja irgendwohin, die geht immer zulasten der Spindel zulasten der ganzen Maschine zu Lasten der Fräswerkzeuge etc. Beim Laser hab ich ein Energieeintrag von 100 -, 200 Watt hab keine mechanischen Teile außer der Schieber das Berlin und Herschiebt ja aber Optik also das ist ein Summe. Ich kann auch ein Laser wesentlich länger nutzen als eine Fräsmaschine. Weil ich weniger Energie brauche, um das Objekt herzustellen.

Bolliger Martin (bollima2)

Okay und vielleicht dazu noch wie oft müssen Sie die Drucker warten? Oder haben Sie da auch Unterstützung von der der Firma, wo sie die Drucker kaufen, wie, wie es da das Verhältnis auch wird, da Support geleistet, unterstützt und vielleicht auch von ihrer Seite Tipps gegeben, was sie in Zukunft in der Maschine noch ergänzen sollten oder verbessern sollten?

Manfred Goth

Also in der Tat ist so zu Beginn war der Aufwand von Seiten der Lieferanten hundert Prozent. Ne Maschine am Laufen zu halten, sag ich mal mit allem was dazu gehört. Der ist jetzt eher bei 20%, weil wir natürlich auch entsprechende Berufe eingestellt haben. Industriemechaniker oder Feinmechaniker, die das dann gelernt haben bei der Größenordnung, wo wir unterwegs sind, können wir es uns gar nicht leisten. Das wir das vom Lieferanten machen lassen, das müssen wir selber machen.

Bolliger Martin (bollima2)

Ah okay, also sie haben selber Mitarbeiter, die sich darum kümmern und die Wartung vornehmen?

Manfred Goth

Genau.

Bolliger Martin

Ja und vielleicht noch zu der Nutzung von Strom etc brauchen ist jetzt zu einer Fräsmaschine, wo sie genannt haben ist da der Kostenvergleich ähnlich mit dem Verbrauch, oder ist jetzt der Strom extrem viel höher bei einer 3 d Druckmaschine?

Manfred Goth

Also pro Stunde ist der Stromverbrauch identisch. Laser, die Laser arbeiten, mit 200 Watt. Es gibt welche mit 400 Watt. Dann habe ich noch ein bisschen Energie, die natürlich die Elektronik braucht. Die Fräsmaschine diese Motoren brauchen auch nicht wesentlich mehr, aber ich Krieg halt pro Leistungsaufnahme mehr Bauteile hergestellt.

Bolliger Martin (bollima2)

Vielleicht eine Frage für in die Zukunft. Wo sehen Sie geht das noch hin mit der additiven Fertigung sehen sie, weil es gibt in der Theorie gewisse, die sagen, es wird so weit gehen, dass der Zahnarzt alles über den 3 D Drucker selber drucken kann, gibt aber auch Theorien, die sagen, das wird immer bestehen bleiben, dass Labore noch dazwischen sind. Wege neben der Verarbeitung auch noch die Ästhetik, was ja wieder ein Unterschied ist zum normalen Zahnarzt Beruf selber. Wo sehen Sie, geht das hin, in die in den nächsten Jahren?

Manfred Goth

Das ist jetzt meine ganz persönliche Sicht der Dinge? Es wird Zahnersatz geben, der vollautomatisiert hergestellt werden wird. Da reicht ein intraoral Scan aus. Und das komplette Konstruktion des komplette Design wird Vollautomatisiert stattfinden. Shape arbeitet, da mit Hochdruck dran, Algorithmen zu entwickeln. Die Konstruktion und Design automatisieren. Es wird Zahnersatz geben, der kann völlig ohne Zahntechnik hergestellt werden, das wird es geben. Er wird aber nicht alle Therapien ersetzen können, die man braucht. Also die ganzen Anforderungen ist der Mensch ist so individuell. Und die Anforderungen, Zahnlücken zu schließen etc sind ja auch zum Teil sehr komplex. Einfachere Restorationen, einfachere Therapien kann auch ich mir vorstellen. Sie wird den Computer mit einer Maschine voll

automatisiert durchführen, glaub ich kein Zahntechniker mehr. Jetzt haben wir in Deutschland einen sehr hohen Level an Zahnheilkunde. Da werde ich noch lange viel Zahntechnik dazwischen brauchen. Der Rest der Welt hat keinen so hohen Anspruch an Zahnersatz. Und es gibt weltweit Bestrebungen Zahnersatz vollautomatisiert herzustellen. Nicht komplett zu ersetzen, aber gewisse Arten von Zahnersatz oder gewisse Arten von Therapien kann ich mir vorstellen in 5 - 10 Jahren laufen die vollautomatisiert. Da reicht ein Scan vom Zahnarzt. Der schickt den Datensatz irgendwohin. Da wird alles voll automatisiert erledigt. Er bekommt eine Woche später ein Packerl und da hast du den fertigen Zahnersatz drin. Direk beim Zahnarzt also Chairside, da gibt es Versuche gibt es ja schon inlays, onlays, Heilkronen, dass die in der Praxis gleich gefräst werden. Das hängt auch wieder ein bisschen von den Werkstoffen und von den Indikationen ab. Alles, was ich aus Kunststoff drucken kann ich auch in der Praxis drucken. Sobald ich Metall oder Keramik oder vielleicht auch Pique eines Tages drucken kann. Wird der Aufwand schon deutlich größer, was Investitionen in die Maschine, auch in die vor und nachgelagerten Prozesse, das unterschätzen viele? Weil es ist ja nicht damit getan, jetzt so ein Leser hinzustellen, da hängt ja vorne dran ein riesen Pre-Prozess und hinten dran auch nochmal ein Riesen Post Prozess den unterschätzen die meisten.

Bolliger Martin (bollima2)

Ja, weil es ist, ja auch wie sie sagen man muss ja das dann auch am Computer zuerst bearbeiten etc und das wird dann meistens nicht erwähnt, sondern eben man nimmt dann schon anders der Computer alles selber macht, aber dazu dauert es wahrscheinlich noch ein bisschen Zeit bis das soweit.

Selbst wenn der Drucker fertig ist alsowenn der additive Fertigungsprozeß zu Ende ist, hab ich ja noch kein fertiges Produkt, muss es ja aus der Maschine rausholen. Ich muss es nachbearbeiten. Also da steckt immer noch Handarbeit drinnen, das unterschätzen viele noch ja.

Bolliger Martin (bollima2)

Ja, vielleicht noch zu zum Qualitätsmanagement, wie überprüfen sie nach dem Druck die Qualität gibt es da Maschine, welche sie nutzen, um die Qualität zu überprüfen oder wird das noch vom Auge gemacht?

Bolliger Martin (bollima2)

Also Hauptqualitätsprüfung ist Augenschein, unser Hauptqualitätsmanager ist unser Kunde. Wir können es uns nicht leisten, schlechte Qualität zu liefern, weil das ist über Social Media sofort in allen Kanälen. Also unser stärkster Kontrolleur ist unser Kunde. Die Zufriedenheit der Kunden. Wir machen regelmäßig Schliffbilder. Wir setzen immer wieder mal Bauteile auf die Platte, die wir dann durchtrennen, wo wir Schliffbilder machen und unter Mikroskop fotografieren für unsere eigene Dokumentation. Wir haben schon mal überlegt, ein Röntgengerät anzuschaffen. Wenn wir noch weiterwachsen und auch die Kontrolle automatisieren wollen, müssen wir über solche Systeme nachdenken. Momentan ist das immer noch Endkontrolle visuell. Und in dem Bemühen, im Vorfeld alles richtig zu machen, weil wir es uns gar nicht leisten können bei unseren Kunden einen schlechten Ruf zu bekommen. Ja, sehr trivial ist es auch. Aber funktioniert bis jetzt hervorragend.

Bolliger Martin (bollima2)

Okay? Und die die Teile, die sie drucken und dann verschicken, ist das dann so, dass der Kunde sagt ihnen, wir brauchen diesen Part von der Krone und sie drucken den und er macht dann den

Rest oder wie funktioniert das, wenn sie so viele individuelle Modelle vorbereiten, wie funktioniert das das reibungslos abläuft?

Manfred Goth

Da steckt viel Erfahrung drin. Wir haben Leute, die 10 oder 15 Jahren hier im Betrieb sind oder länger, also, das ist einfach ganz viel Erfahrung, ganz viel Fleiß von den Mitarbeitern, viel Engagement. Wir denken über zunehmende Automatisierung nach. Ja wohl wissend, dass hundert Prozent Automatisierung nicht geht. Aber wir haben Projekte, wo wir schauen welche Prozesse können wir noch mehr automatisieren durch Maschinen ersetzen? Wir haben natürlich auch einen hohen Personaleinsatz. Hier im Haus wo noch viel handwerkliche Tätigkeit, da ist anders ist das mit der Größenordnung noch gar nicht stemmbar.

Bolliger Martin (bollima2)

Vielleicht nur noch zum Thema Innovation, stehen sie da auch in Verbindung mit 3 D Druck Firmen, wo sie sich öfters austauschen. Oder welche Produkte sie noch gerne haben würden oder welche Drucker Möglichkeiten Sie noch gerne hätten, die vielleicht bis jetzt noch limitiert sind.

Manfred Goth

Also in der Tat ist es so wir sind ja gestartet mit Metall 3 D Druck, additive Fertigung von Metallen. Da war natürlich der Hersteller. Der Haupt Know-How Lieferant. Beim Edelmetall war so wie man Edelmetall, Druck, das haben wir hier im Haus selber herausgefunden. Wir haben bei der Parametrisierung der Maschine haben wir uns eine Hochschule zu hilfegeholt aus der IT. Aber rauszufinden, wie man mit dem, wie man mit dem Material Edelmetall umgeht, um es drucken zu können, das war einfach Forscherdrang von Zahntechnikern hier im Haus. Wir haben jetzt mittlerweile ein sehr hohes Know How im Bereich Additive Fertigung. Im Bereich, Keramikdruck ist es so, dass wir tatsächlich mit dem Hersteller Vierzehntägiges Meeting schon fix haben. Die uns helfen, das zu lernen, die wiederum von uns lernen, weil Zahntechniker sind sehr findige Menschen sehr neugierige Menschen, auch mit einem ständigen, experimentiert trieb. Und wir gehen mittlerweile echte Forschung, Entwicklung, Kooperationen mit Hochschulen ein, wo wir wirklich auch renommierte Hochschulen haben, mit denen wir echte Grundlagenforschung und oder Entwicklungsprojekte haben. Um A, die Fertigungstechnik zu optimieren. Und jetzt haben wir das erste Projekt, wo man auch überlegen, eigenen Werkstoff zu entwickeln.

Bolliger Martin (bollima2)

Und das und das heißt auch Sie haben auch Innovation, also in sie betreibt auch Nachforschung innerhalb der Firma hab ich so, wenn ich das richtig verstanden habe?, also es wird auch oft innerhalb der Firma ausprobiert und versuchen,

Manfred Goth

Wir haben sehr kreative Leute im Unternehmen, die dürfen sich frei austoben. Und in den letzten 15 Jahren war der Inhaber, der hat da viel Druck gemacht zu sagen, wir müssen schauen, dass wir auch innerhalb der Zahntechnik innovativ sind. Das sind auch gute Ideen entstanden auch jetzt aktuell. Wir haben auch jetzt Grad ein Projekt in der Zahntechnik, wo wir Zahntechnik, wo wir eine gewisse Art Zahnersatz rein digital von weitgehend automatisiert herstellen können. Wir schreiben grad das Patent. Also Gott sei Dank haben wir sehr neugierige, sehr kreative Köpfe im Haus und die haben auch den Freiraum, hier sich austoben zu können.

Bolliger Martin (bollima2)

Okay, interessant ja, das ist gut zu hören, ja das, das waren eigentlich mehrheitlich meine Fragen soweit. Ich danke Ihnen vielmals, dass Sie sich die Zeit genommen haben dir gerne.

Bolliger Martin (bollima2)

Und ja, war sehr interessant zu hören von von jemanden, der schon unter eine Firma, die schon so weit ist und schon so effizient die additive Fertigung nutzt. Ich sehe da Ihre Firma ist der einer der Vorreiter, wenn ich das mit anderen Firmen vergleiche, weil bis jetzt hab ich auch herausgefunden, dass viele noch auch skeptisch sind gegenüber der Technologie oder halt sagen sind noch nicht die Materialien vorhanden. Für diese gerne dann die Zahnkrone an sich hätten.

Manfred Goth

Ist verständlich der Zahnheilkunde Markt. Deutschland ist Reich, Schweiz ist sehr traditionell denkend, hat Vorteile aber auch. Der Vorteil ist es etabliert sich was und man kann lange daran partizipieren. Der Nachteil ist, dass natürlich Innovationen Mann läuft Innovationen hinterher.

Bolliger Martin (bollima2)

Und vielleicht noch ne Frage können Sie haben Sie jetzt die Möglichkeit, dass Ihre Firma wesentlich günstiger im Verhältnis liefern, also können durch die additive Fertigung wirkt sich das auch auf ihr Preisangebot im Vergleich zur Konkurrenz oder sind sie da ich, dass Sie sagen die Qualität ist so hoch auch von unseren Druckern, dass wir da einfach also quasi dass ihre Marge bleibt und sie da nicht groß verändern an der Kostenstruktur.

Manfred Goth

Muss jetzt aus 2 Perspektiven sehen. Wir versuchen, den am Markt erzielbaren Preis möglichst nicht zu unterwandern. Gleichzeitig wir ganz klar das Ziel, Kostenführer zu sein, Kostenführer und Qualitätsführer zu sein. Aber nicht mit dem Ziel, die am Markt erzielbaren Preise zu unterwandern. Okay, könnten dies für Kampagnen nutzen. Aber wir nutzen den Spielraum natürlich aus, um unsere Überlebenssicherheit zu gewähren. Wir sind sicher also, wir sind überzeugt davon, dass wir in weiten Bereichen Kosten Führer sind. Und wenn auch immer irgendjemand versucht mit Rabatten oder was auch immer Ja, Preise zu drücken, da kann man immer entspannt auch mitgehen im Falle des Falles okay ja, aber wir haben das klare Ziel aufgrund unserer Fertigungstechnik. Qualitäts und Kostenführer zu sein.

Zieht sich durch alle Bereiche durch, auch wenn wir investieren, ist klar. Ohne das aber gleich sofort an den Markt weiter zu geben.

Bolliger Martin

Vielleicht noch sie haben ja gesagt, dass auch ein großer Teil ihres Geschäftes auch in Frankreich und Italien stattfindet. Kunden da sind haben sie da in Zukunft ein bisschen die Sorge, dass dann diese Länder auch die additive Fertigung selber einführen? Das heißt, dass sie nicht mehr auf sie angewiesen sind oder wie gehen Sie dieses Risiko an?

Weil wahrscheinlich auch die Transportkosten höher sein werden. Und wie gehen Sie mit dieser Veränderung um?

Manfred Goth

Das oberste Ziel ist Kostenführerschaft. Da haben wir ein Paar Ideen, wie wir das beibehalten können, die gebe ich aber natürlich nicht preis klar jetzt in Frankreich, Italien von Haus Ausländer.

Die weit unter dem Preisniveau Deutschland liegen. Dort gibt es auch schon vergleichbare Fertigungszentren. Da ist kuriose Weise Made in Germany unsere Marktvorteil weil wenn bei uns einen Liefertermin drauf steht, dann kriegen die das auch zu dem Liefertermin und da zählt dann wirklich Made in Germany und die Zuverlässigkeit da geht es gar nicht um den Preis und das halten wir natürlich so. Da versuchen wir nicht mit französischen oder italienischen Playern mitzuhalten, sondern da spielen wir unsere Vorteile aus Qualität, Zuverlässigkeit, Geschwindigkeit.

Bolliger Martin (bollima2)

OK ja super dann vielen Dank für die interessanten Einblicke. Ich würde sonst hier mal kurz die Aufzeichnung aufhören.

Appendix H: Interview with Dr. med. Dent. Helen Mang Buckman

Interview Partner:	Dr. med. dent. Helen Mang Buckman
Role	Dentist, practice owner
Company	Dental Surgery Mang Buckman
Interview Type	Dentist
Date/Time:	06.05.2022 / 15:30
Interview Duration	33 Minutes 19 Seconds
Interview Language	German
Format	Online

Bolliger Martin (bollima2)

Also dann würde ich kurz mich selbst noch mal vorstellen ich heiße Martin Bury, gelte bin in meinem letzten Semester von meiner Bachelorarbeit und habe dort das Thema Zentralisierung oder Dezentralisierung im Zusammenhang mit der additiven Fertigung und habe mich dazu entschieden, dieses spezifisch anzuschauen. Im Zusammenhang mit Zahlen Kronen und die Themen, die Fragen, die ich dazu stellen werde, beziehen sich primär auf Kostenmanagement, Qualitätsmanagement, Prozessmanagement und Innovationsmanager. Nun will ich Ihnen kurz das Wort gerne übergeben Frau morgen, um sich selber kurz vorzustellen und vielleicht etwas über ihren beruflichen Werdegang wiederzugeben und dann können wir starten mit den Interviewfragen.

Helen Mang Buckman (Gast)

Ja, herzlichen Dank also mein Name ist Helen Mang Buckman, ich betreibe hier eine Zahnarztpraxis, eine all gemeinsame Praxis in Herrliberg. Wir sind ein Team von 2 Zahnärzten 3 Dentalassistenten, einer Prophylaxe Assistentin, eine Dentalhygienikerin. Seit 7 Jahren betreiben wir die Praxis zusammen. Ich habe an der Universität in Zürich studiert, habe 2004 das Staatsexamen gemacht, habe 2008 promoviert auch in Zürich. Ich war in diversen Praxen tätig als Assistenz Zahnärztin, bevor ich dann die Praxis hier in Herrliberg eröffnet habe. Ich habe ein Weiterbildungsausweis in allgemeiner Zahnmedizin. Das beinhaltet nebst den Kronen Brücken auch Implantat Fälle genau und das ist auch das Angebot, was wir da in der Praxis auch offerieren.

Bolliger Martin (bollima2)

Okay, dann wäre meine erste Frage dazu ist, wie ist Ihr derzeitiges Vorgehen, wenn, Sie feststellen, dass ein Kunde eine Zahnkrone benötigt, also was ist der Ablauf?

Helen Mang Buckman (Gast)

Also wenn es um eine Zahnkrone geht, im distalen Bereich aus eben im Molaren Backenzahnbereich schwieriger ersichtlich ist es eigentlich so, dass wir immer direkte Kronenrekonstruktionen machen, das heißt, wir präparieren diesen Zahn. Wir formen diesen Zahn direkt in der Praxis Digital App mit einem Zerec System mit einem Cat Cam System und Schleifen die Zahnkrone aus einem Keramikblock und setzen diesen da ein. Das handhaben wir eigentlich immer so, wenn es um einen hinteren Bereich geht. Sind Zähne betroffen im Hoch ästhetischen Bereich dann läuft es eigentlich ab, dass wir das zuerst mit dem Zahntechniker absprechen. Meist kommt der Zahntechniker schon am ersten Tag bevor das der Zahn geschliffen wird vorbeikommt und die Farbe genau aufnimmt. Dann wird der Zahn prepariert, dann wir dann digital einen Abdruck geformt, die Daten werden im Labor versendet, ja, dann

gibt es einen Termin für eine einfache, Einprobe und Farbbestimmung und dann die Zementierung.

Bolliger Martin (bollima2)

Okay, und das heißt bei den hinteren Zähnen können Sie das direkt vornehmen, wenn der Patient beim ersten Besuch kommt und sie das Feststellen also wird das dann direkt für den Patienten hergestellt?

Helen Mang Buckman (Gast)

Im Molarbereich machen wir wirklich eine Direktversorgung das heißt, der Patient kommt der Zahn wird präpariert wird abgeformt und rekonstruiert gleich im Computer auf dem Scanner sozusagen, dann geht der Keramikblock in die Schleifeinheit eingesetzt und meist geht es so zwischen 7 - 14 Minuten, dann ist der Zahn geschliffen und dann wird er in der gleichen Sitzung nach einer kurzen Pause für den Patienten, wobei ich die Pause gerne nutze und noch schnell etwas anderes mache. Beim Patienten wird der Zahn eingesetzt, für so eine direkte Kronenversorgung rechne ich immer etwa eineinhalb Stunden ein und dann ist der Zahn eigentlich versorgt plus ein Plus für uns, da wir alles in einer Sitzung machen können, auch alles selbst in eigener Regie natürlich umsetzen können. Ein Plus auch für den Kunden da er sozusagen die provisorische Versorgung spart den ganzen zahnärztlichen Zahntechnischen teil natürlich nicht auf die Rechnung mitbekommt. Nur einmal kommen muss genau das ist so ein bisschen der Vorgang.

Bolliger Martin (bollima2)

Und das Material ist das, Keramik oder was?

Helen Mang Buckman (Gast)

Da gibt es mittlerweile gibt es ganz verschiedene Arten von Keramiken gibt es auch Kunststoffblöcke. Hier also ich ja, es gibt ganz, ganz hochwertige Keramik, die man dann auch später noch glasieren kann. Das mach ich jetzt hier das selber noch nicht. Das hatte ich in meiner früheren Praxis haben wir eigentlich meist dann das auch noch glasiert und den Patienten dann über Vormittag und Nachmittag einbestellt und konnte man hier die Kronen noch individualisieren und anmalen und anfärben. Das mach ich im Moment nicht, ist auch je nachdem gar nicht Kundenwunsch in diesem Sinne aber da kann man sich natürlich noch ein bisschen mehr verewigen.

Bolliger Martin (bollima2)

Wie oft haben Sie Kunden, die eine neue Zahnkrone brauchen? Wenn man jetzt so ein Monat oder aufs Jahr anschaut?

Helen Mang Buckman (Gast)

Oh, das ist schwierig zu sagen, also die eigentliche Zahnkrone bei einer Zahnkrone geht es ja darum, dass man wirklich zirkulär vom Zahn etwa ein Millimeter weg gibt. Das wird natürlich immer weniger gemacht heutzutage man versucht eigentlich ist man der Auffassung versucht eigentlich den Zahn so wenig wie möglich zu beschleifen. Das heißt, wenn jemand eine große Amalganfüllung hatte und diese Amalganfüllung ist gebrochen. Ich sehe, es hat nur noch eine ganz kleine Wand, dann mach ich meist also eine ganz kleine Restwand, dann mach ich meistens keine Krone mehr. Früher haben wir dann eine Krone gemacht und heute machen

wir dann aus dieser Keramikmasse so wie ich es ihnen erklärt habe, macht man dann einen Overlay oder. Man beschleift den Zahn nicht zirkulär, sondern lässt diese Wand bestehen, die noch da ist. Und klebt einfach die Keramik Versorgung an den Rest an die bestehende Wand an also es wird nicht aufgesetzt, sondern angeklebt und zum Teil, wenn die bestehende Wand ganz dünn nicht und wird diese noch weggeschliffen, dann wird schon wie eine Krone das auch drüber geklebt, aber man versucht eigentlich so viel vom Zahn noch zu behalten und das machen wir relativ häufig. Also das haben wir heute gemacht, wir machen das vielleicht einmal in der Woche.

Bolliger Martin (bollima2)

Vielleicht noch zu der Krone selber das wird dann, hab ich das richtig verstanden, Sie haben da auch eine Maschine dazu?

Helen Mang Buckman (Gast)

Wir haben so eine Schleifmaschine genau. Genau, ja und da gibt es mittlerweile also das System dieses Cerec System. Das wurde in Zürich erfunden hat vor etwa 50 Jahren. Das ist so, das Alt, ja, das standardisiertes Modell und , da hat man diesen Scanner, diese Aufnahmeeinheit die ist kompatibel mit der Schleifeinheit miteinander und es konnte nur mit dieser Cerec Aufnahmeeinheit die Schleifmaschine bedient werden. Heutzutage etwa 15 Jahre oder seit etwa 10 Jahren ist der Scanning Markt im Dentalbereich fast explodiert. Es gibt jetzt Dutzende neue Scanner früher hatte es nur diese Aufnahmeeinheit von diesem Zerec und das Problem ist ein bisschen, dass viele Scannen nicht mit dieser Schleifeinheit kompatibel sind. Viele Scanner haben ihren eigenen Schleifbereich oder ihre eigene Schleifeinheit in die ganze Maschinerie mit einbezogen und das ist für uns. Deshalb haben auch wir haben einen Scanner für die Transkription oder Versand ins Labor und machen eigentlich für alle in-house Geschichten noch mit dem eher alten mit der alten Aufnahmeeinheit diese Versorgung mit unserer internen Schleifeinheit. Die Schleifeinheit, die wir haben, ist relativ groß. Also wir könnten auch ganze Brücken herausschleifen lassen. Brücken, mach ich eigentlich nicht mit dieser Schleifeinheit nur provisorische Brücken dann setze ich statt einem Keramikblock einen Kunststoffblock ein und dann schleift ein bisschen länger, das geht dann vielleicht etwas machen. Über Mittag lasse ich wieder schleifen. Es geht vielleicht eine Stunde und kann das nachher einsetzen. Brücken habe ich immer noch gerne über den Zahntechniker.

Bolliger Martin (bollima2)

Vielleicht direkt zur nächsten Frage, bezüglich den Materialien, gibt es da auch unterschiedliche Anwendungen, je nachdem wo der Zahn sitzt oder gibt es da von ihrer Seite auch Präferenzen, welches Material verwendet wird für die Kronen?

Helen Mang Buckman (Gast)

Ja, dann mach ich eigentlich immer so, wenn es jetzt eine Krone ist eine normale Keramikkrone, dann mach ich im hinteren Bereich mach ich nur monolithische zirkon Kronen. Das heißt, es sind Kronen, die haben eine Zirkon Gerüst und dass die ganze Krone wird aus der gleichen Masse hergestellt und wird dann einfach oben drüber noch mit Farben schön bemalt. Dass man eine verblendete Krone macht. Das heißt, ein Gerüst macht mit dem Zirkonoxid und dann verblendet das kann man auch machen, das mach ich nur, wenn es ein bisschen in in den höheren ästhetischen Bereich kommt, dass man dann noch eine zusätzliche Blendmasse hat. Also im Molaren Bereich benutze ich eigentlich immer monolithische Zirkonkronen, dann ab dem prämolaren Bereich bei eher ästhetisch anspruchsvollen Kunden nehme ich dann ähm EMAX. Also Glaskeramik sozusagen, das kommt ein bisschen auch drauf an ist der Zahn schon

vorbehandelt. Ist er zum Beispiel Wurzel behandelt, dann ist sehr dunkel, dann kann ich nicht mit einem lichtdurchlässigen Material arbeiten. Dann kann ich keine Emax Krone draufsetzen, aber sonst im Frontbereich mach ich eigentlich alles aus Emax.

Bolliger Martin (bollima2)

Auf welchen Faktoren beruhen die die Kosten dann von der Zahnkrone selber, wenn sie jetzt zum Beispiel, wenn sie die vor allem vom Labor, her weiß ich, dass sie da die Preise dann übernehmen, vom Labor kommt? Aber wenn sie die selber herstellen?

Helen Mang Buckman (Gast)

Mhm wir haben ja also, ich bin eine Zahnärztin im Verein SSO Zürich. Da haben wir ganz fixe Tarife, Richtlinien, Tarif Leistungen, die wir einfach abrechnen und diese Cerec Versorgung, ist einfach eine Tarifposition also, da kann ich gar nichts verändern, also wenn es ein eine Zahnkrone ist, direkt angefertigt über das Cerec dann sind das 960 Franken für die Krone selber. Wenn ich das noch vor behandeln muss und ja, das im Ganzen kostet 1000 Franken und eine Zahnkrone über den Zahntechniker ist die um einiges teurer.

Bolliger Martin (bollima2)

Haben Sie schon von dem 3 D Druck gehört? In der Zahnmedizin an sich?

Helen Mang Buckman (Gast)

Ja also ich denke ganz fest am Rande ja bin ich vielleicht schon mal darüber gestolpert, aber ich habe jetzt nicht etwas Konkretes im Kopf, dass ich jetzt genau berichten.

Bolliger Martin (bollima2)

Bei ja, vielleicht werde ich doch kurz erklären kann die die Idee ist oder weshalb auch meine meine Forschungsfrage in die Richtung geht, ist, dass man sagt das mit dem 3 D Drucker der halt Schicht für Schicht aufeinander aufbaut, wäre der Vorteil in der Zukunft, dass man kein Material Ausschuss mehr hat und man hat halt auch festgestellt, dass gewisse Drucker Zahnkronen in 20minuten drucken können. Also ich weiß jetzt halt nicht, wie das dann aussieht. Für den ästhetischen Bereich. Ob das derselbe Fall ist, aber so, wie sie es ja geschildert haben, kann schon die Fräsmaschine ähnlich schnell vor allem für die Molaren. Aber die die Zähne drucken, aber wir sehen Sie einen Vorteil in in der Additiven Fertigungsweise für sich selber oder für Ihre Praxis in Zukunft?

Helen Mang Buckman (Gast)

Also additiv hergestellt anstatt eigentlich Ausgefräst, so meinen Sie?

Helen Mang Buckman (Gast)

Ja vielleicht der Vorteil wäre ein bisschen, dass man das ja, aber ich weiß nicht, ob man das wirklich umsetzen kann, das natürlich vielleicht Farb technisch das noch besser hinbringen würde, also ja, aber das wird wahrscheinlich schwierig umsetzbar. Der Zahn hat mehrere Schichten und wenn es darum geht, jetzt eine Versorgung aus diesem Keramikblock zu schleifen, dann wird heutzutage schon mit stark eingefärbten Keramikblöcken gearbeitet. Das heißt der Keramikblock ist unten schon bisschen dunkler als oben. So dass man schichtweise, wenn der Zahn nachher aus diesem Keramikblock gefräst wird, also dann schon verschiedenfarbige eigentlich ist. Und wenn man jetzt im additiven Verfahren eigentlich dass

von dieser Seite her beleuchten würde, könnte man vielleicht ich weiß es nicht, aber der Kern Farbe ist schon ein bisschen anders aufbauen also man könnte den vielleicht noch ein bisschen mehr strukturieren, weil wenn es darum geht, auch nicht mit Keramik, sondern mit Kunststoff einen Zahn aufzubauen. Dann geht man ja auch schichtweise vor und dann nimmt man halt auch immer wieder, je nachdem, wo das man etwas ansetzt, wieder eine andere Farbe und legt die Formen dann übereinander und das gibt diesen spezifischen Farbeffekt, aber das wird wahrscheinlich schwierig, dann umsetzbar sein aber ja.

Bolliger Martin (bollima2)

Also in den Modellen können Sie das bereits herstellen? Ich hab mit einem mit einer 3 D Drucker Firma gesprochen und die weil sie halt die Zertifikate noch nicht haben. Für längerfristig, den der die das der Zahlen auch im Ja wie sagt man dem, dass er bleiben darf und nicht nur für vorübergehende Benutzung, aber die können auch schon verschieden farbig aufbauen, also auch mal zum Beispiel für größere Firmen, wo ganze Kiefermodelle, können sie auch das Zahnfleisch und alles in unterschiedlichen Farben wiedergeben. Die Frage ist halt, ob es mit im Zusammenhang mit dem Keramik dann diese Möglichkeit geben wird?

Helen Mang Buckman (Gast)

Aha, wenn ich jetzt sagen gehen würde Material, Material, Verschleiß minimieren, das jetzt im Gegensatz zu einem Keramikblock da bleibt, wenn man den richtigen Block einsetzt, bleibt nach dem herausfräsen nicht viel. Es gibt Keramikblöcke in unterschiedlichen Größen und also jetzt gleich heute habe ich so eine wirkliche Krone gemacht. Dann nehme ich den kleinsten Block, wenn s Ihnen ein kleiner Zahn ist, also wird mit direkt angegeben vom Computerwas für ein Keramikblock reichen würde von der Größe und wenn man dann den entsprechenden Block denn eigentlich nimmt, dann bleibt wirklich nur noch einen Restbestand übrig vom eigentlichen Block von dem her bin ich jetzt das Materialmäßig völlig vertretbar.

Bolliger Martin (bollima2)

Okay und vielleicht noch, wenn sie jetzt den Zahn für die hinteren Molaren selber herstellen? Hatten Sie da schon Fälle irgendwie Probleme mit dem Material oder der Qualität oder das irgendwie beim beim Patienten später irgendwelche Vorfälle aufgetreten sind?

Helen Mang Buckman (Gast)

Ja, es gibt natürlich immer irgendwann irgendwelche Komplikationen, aber ich muss sagen, ich mache viele von diesen direkten Cerec Versorgungen und dann hat man vielleicht eines in 4 Jahren das mal Probleme macht, dass man das irgendwo ein Teil abbricht oder ich weiß es jetzt bin ich 7 Jahren in Herrliberg und ich weiß jetzt ein Fall, da hab ich es nochmals geschliffen, weil es irgendwie weiß auch nach einer Woche gebrochen ist, weil es wahrscheinlich irgendwo zu hoch ist. Also man muss natürlich das Material schreiben, bisschen kennen und wenn man jetzt sagtman hat noch einen Glasofen, man kann auch noch hochwertige Keramik nehmen, dann kann man eben ganze Brücken schleifen, wenn sehen würde, dass immer welche Versorgungen brechen würden, würde das wirklich am Material liegen, weil die Keramik, die ich jetzt benutze. Das ist, wenn man das vom Kräfteverhältnis her anschaut, ist das jetzt im mittleren Drittel oder könnte man jetzt sagen würde das bricht immer dann könnte man einfach einen hochwertigeren Keramikblock einsetzen. Das sind meistens auch Zirkonblöcke oder Emax Blöcke, aber die muss man nachher im Ofen nochmal nach synthern, aber das hat sich für mich nie ergeben, weil ich wirklich fast keine Komplikationen hatte. Das war so ein Projekt vor 2-3 Jahren habe ich mir verschiedene Ofen angeschaut, eben weil ich das früher auch oft gemacht habe, aber wenn man jetzt eigentlich immer schaut, dass genügend Zahlen vorhanden

ist und genügend Klebefläche da ist und das Material vor allem auch genügend dick ist das ist halt eine Erfahrungssache wenn das Keramik zu dünn ist, kann das einfach brechen.

Bolliger Martin

Okay okay, aber wenn sie jetzt, wenn der Blog für die hinteren Molaren oder der die Krone herauskommt, müssen sie dann noch? Was müssen Sie am Zaun noch machen, müssen Sie dann noch irgendwas weiter präparieren oder ist er dann direkt Einsatz fertig?

Helen Mang Buckman (Gast)

Außer jetzt generell oder wenn es irgendeine Komplikation wäre, also wenn.

Bolliger Martin (bollima2)

Nein, generell.

Helen Mang Buckman (Gast)

Zum Beispiel heute hab ich den Zahn zuerst, ein mit Kunststoff ein bisschen aufgebaut, dann habe ich geschliffen, rundherum geschliffen wie für eine Krone, weil der Zahn so dunkel war, dann habe den digitalen Abdruck gemacht sind digitalen. Dann habe ich das Schleifen lassen. Es ging genau 8minuten. Und dann wird die Krone von meiner Assistentin vorbehandelt. Ich mache am Zahn nichts mehr ich schleife nichts mehr, ich reinige nur noch den Zahnstumpf. Und mache wie bei einer Füllung appliziere ich Klebemittel und ich nehme dann eigentlich fast normalen Kunststoff und verklebe die Zahnkrone mit dem Zahn. Aber ich Schleife nachträglich nichts mehr ich schleife nachher eigentlich nur noch die Rekonstruktion ein, obwohl mit dem ganzen System kann man verschiedene Parameter schon vorher Einstellen das heißt, ich kann genau schauen wie fest ist mein Kontakt zum Nachbarzahn. Ich kann den Zahn, jeden Höcker kann ich eigentlich variieren und selbst noch nachformen. Ich mache da lieber ein bisschen mehr Kontakt zu Beginn und Schleife dann ein bisschen wieder ein. Es gibt Leute, die haben die Parameter genau so eingestellt, dass sie nacher fast nichts mehr schleifen müssen an der Rekonstruktion ich schleife noch immer gern und poliere dann zum Schluss.

Bolliger Martin (bollima2)

Ja, vielleicht, ich habe auch noch eine Frau zu den Mitarbeitern, haben die pro Jahr oder haben sie vielleicht auch selber Weiterbildung, wo neue Methodiken oder Technologien vorgestellt werden?

Helen Mang Buckman (Gast)

Also jetzt im Kronenbereich oder ganz allgemein.

Bolliger Martin (bollima2)

Ganz allgemein eigentlich ja.

Helen Mang Buckman (Gast)

Ja, also innerhalb der SSO Zürich ist man ja verpflichtet, dass man 80 Stunden Fortbildung betreibt im Jahr und von diesen 80 Stunden sind 30 Stunden Selbststudium und 50 Stunden sind nachweisliche Weiterbildungsstunden. Ja, muss man 50 Stunden nachweisen können, also das heißt ähm ja, und wir sind ständig in der Weiterbildung. Ja, auch mein Team wird aufgefordert zur Weiterbildung.

Bolliger Martin (bollima2)

Ja.

Helen Mang Buckman (Gast)

Genau das läuft dann ein bisschen über mich, dass ich da einige oder sie haben selbst konkrete Ideen. Aber ja, ich bilde mich vor allem auch weiter in Sachen, wo ich merke, da hab ich noch. Da gibt es viele neue Technologien, aber es war ganz lange der Fall in der ganzen digitalen Abformung. Das war ein großes Spektrum, oder in der Implantologie, aber da ist man eigentlich verpflichtet, wirklich diese Fortbildungsstunden ja einzuholen. Das wird wirklich auch geprüft wir wurden nachgeprüft etwa vor 2 Jahren und dann muss man über die letzten Jahre diese Nachweise erbringen können.

Bolliger Martin (bollima2)

Ich habe noch eine Frage vielleicht wie würden Sie sich selber beschreiben, als eher traditionell moderne oder innovative Zahnärztin?

Helen Mang Buckman (Gast)

Ich interessiere mich sehr für neue Innovationen. Ich springe aber schon nicht gleich auf jeden neuen Zug auf also ich hab gerne altbewährte Sachen, aber mit einem großen Weitblick eigentlich. Nein, ich bin nicht altmodisch sind wir ganz sicher nicht also ich habe gerne Innovation, das ist mir sehr wichtig. Auch mit der Uni Zürich, so indirekt. Auch zum Schauen was gibt es da auch auf was wird neu gesetzt.

Ja, das ist noch schwierig also.

Bolliger Martin (bollima2)

Aber sie wären sie jetzt zum Beispiel grundsätzlich offen für oder würden Sie jetzt selber sagen wenn jetzt das kommt? Mit der additiven Fertigung das wenn da dann natürlich auch gewisse Studien bestehen, dass sie da sich dann auch Gedanken machen würden, vielleicht das Mal auszuprobieren, weil ich frage, weil in den jetzigen Interviews hat sich ein bisschen gezeigt, dass Zahnärzte generell ja bevorzugen, was schon länger, Wo schon lange Studien darüber bestehen und das verhindert halt teilweise ein bisschen, die neuen Technologien, die die teilweise auch im Ausland schon rege genutzt oder häufig zum Einsatz kommen, sind im Vergleich in der Schweiz noch in den Anfangsschulen.

Helen Mang Buckman (Gast)

Das hat auch mit dem Abrechnungssystem zu tun, weil es sind ja alles Privatkunden, sozusagen Das heisst man schuldet all diesen Kunden schuldet das es funktioniert, da ist natürlich schon versucht ja altbewährte so umzusetzen, dass man da mit gutem Gefühl weißt, dass das hält, aber grundsätzlich ja stimme ich Ihnen dazu. Das verhindert natürlich schon ein bisschen den Fortschritt also ich würde wahrscheinlich auch immer ein bisschen nicht. Hab jetzt ein bisschen wo es darum ging mit dem Scanner hab ich sehr stark auf die Uni Zürich geschaut und geschaut wie läuft bei denen weil die haben so ein bisschen früher umgepolt und haben sich Scanner angeschafft und ich bin da einen guten Kontakt und dann habe ich immer wieder so ein bisschen geschaut was für Scanner sieht bei der Evaluation immer wieder aufs Neue bestellen weil das ist ein bisschen das was sie haben dann die Möglichkeit ganz viele Scanner auszuprobieren ich in

meiner kleinen Allgemeinpraxis muss gleich einen Scanner kaufen und da ist man natürlich schon ja auf gutem Wege, wenn man sich da ein bisschen langsam herantastet und das gleiche ist eigentlich auch mit neuen Technologien. Da macht es natürlich immer Sinn, wenn größere Universitäre Betriebe ja das natürlich leichter an die Kunden bringen können und die Rückendeckung dann eigentlich haben und wenn man merkt, doch da gibt es einige positive Rückschlüsse. Erst dann wird es wahrscheinlich dann in der Allgemeinpraxis auch interessanter.

Bolliger Martin (bollima2)

Ja ich verstehe, weil es geht ja, es sind ja auch meistens größere Investitionen die man man tätigen müsste oder?

Helen Mang Buckman (Gast)

Ja Sie sehen bei der ganzen Scanner Auswahl also ich hatte glaub ich schon vor 4 Jahren war es bei mir so ein bisschen der Wunsch mir zu überlegen, in welche Richtung das es geht und hatte ganz viele Vertreter da aber dann geht es wirklich darum sich zu entscheiden und das ist dann schwierig, weil das funktioniert nicht mit dem das ist so und das ist so und das sind diese Studien wieder anders und ja, es ist gut, wenn man ein Netzwerk von Leuten hat und diesen Erfahrungsschatz auch ein bisschen andocken kann und ja, da geht es um eine grosse Investition.

Bolliger Martin (bollima2)

Ja, würde es ihnen da vielleicht in diesem Zusammenhang in Zukunft helfen also das ist nur ein Gedankengang meiner Seite? Wenn solche Firmen die neue Technologien hervorbringen, vielleicht auch den Zahnärzten ermöglichen das Produkt zu testen anstatt immer direkt, dass es direkt mit einer Kaufverpflichtung verbunden ist, damit sie auch mehr die Möglichkeit haben, Ihre Erfahrungen zu machen, würde das vielleicht helfen?

Helen Mang Buckman (Gast)

Ja klar würde das helfen, und dann braucht es natürlich auch die passenden Kunden dazu, also das ist so ein bisschen das Problem also die müssten ja wie eingereicht sein und bereit sein, für etwas Neues einzustehen, wo man nicht genau weiß, wie es danach wirklich rauskommt und dann ist ein bisschen auch so. Die meisten kommen haben viel zu tun umso schneller desto besser. Das ist an der Universität in einem universitären Betrieb etwas ganz anderes. Wo man einen Studentenkurs hat, die Patienten wissen Sie zahlen nur die Hälfte dafür verbinding sie weiß nicht pro Woche weiß nicht wie viele Stunden mit den Studenten zusammen und da kann man ein bisschen versuchen.

Bolliger Martin (bollima2)

Ach so, das wird dort aktiv. Also da gibt es dann Patienten, die aktiv mit der Uni zusammen das testen oder wie.

Helen Mang Buckman (Gast)

Ja also also während dem Studium ist es eigentlich so, dass man im vierten und fünften Studienjahr arbeitet, man ja schon an einem Patienten immer zu zweit und das sind aufgeklärte Patienten, die sich bereit erklären, zum Teil größere Besorgungen machen zu lassen, zu günstigeren Konditionen. Die kommen an diese sogenannten Studentenkurse, so ein Kurs geht meistens ein ganzes Semester, da muss man wochenweise hin, da ging so eine Krone im

Studentenkurs vielleicht 3 Monate, bis man eine Krone hat und der Patient ist jede Woche vielleicht für 3 Stunden gekommen. Und man hat ein bisschen rumgeschliffen. Man hat wirklich viel Zeit in die Hand nehmen müssen wusste aber man kriegt neueste Technologien. Man ist bestens betreut, hat wahrscheinlich auch irgendwo einen Kulanz Faktor, wenn jetzt irgendetwas nicht richtig funktioniert hätte. Dann würde die Uni Zürich das wieder gut biegen. Und deshalb so eine Institution, so ein Betrieb natürlich schon. Also auch in der Scanner Auswahl, haben sie ganz viele Scans bekommen und immer wieder evaluiert und Daten verglichen und geschaut und Studien gemacht. Ja, sind das solche Betriebsstätten, die können das natürlich viel besser umsetzen und als eigentlich eine kleine Praxis.

Bolliger Martin (bollima2)

Ja, ich sehe und vielleicht noch eine letzte Frage Sie haben ja gesagt dieser der Tarife von der esse. So gibt eine Liste mit den Tarifen wie oft wird die wissen sie das? Wie oft wird die angepasst?

Helen Mang Buckman (Gast)

Das wurde ganz viele Jahre nicht angepasst. Das war auch ein eine starke Diskussions Angelegenheit zwischen der Zahnärzteschaft und ich weiß auch nicht dem Bundesamt für Gesundheit. Ich weiß nicht genau mit wem, dass sie verhandelt haben und der wurde. Ich glaube ich vor etwa 3 Jahren wurde der angepasst oder 4 Jahren. Und die letzten 30 Jahren hat, das hat sie keine Veränderung gegeben.

Deshalb wurden auch Laser Positionen und solche Sachen wurden erst jetzt wieder neu mit dem DENTOTAR das ist der neue Zahnarzttarif wurde das wieder neu eigentlich angepasst. Und es gibt noch heute einige Leistungen vorallem Sozialversicherungsleistungen, die werden immer noch nach dem alten Tarif bemessen. Das ist auch der Grund, warum viele Zahnärzte nicht gerne Sozialfälle behandeln, weil man für die einzelnen Leistungen immer noch soviel bekommt wie vor etwa 30 Jahren.

Bolliger Martin (bollima2)

Ah okay, okay also bei Sozialfällen verdient ein Zahnarzt weniger?

Helen Mang Buckman (Gast)

Ja genau, weil der Tarif noch nicht angepasst ist doch eine große Teuerung in den Zahnarztpraxen stattgefunden hat.

Bolliger Martin (bollima2)

Also eigentlich das kommt zugute dem Bund, der das noch nicht angeben, also dem Staat, der das noch nicht angepasst hat.

Helen Mang Buckman (Gast)

Es gab wirklich große Regulierungen in den letzten Jahr 2 -, 3 Jahren aber es gibt noch Krankenkassen zum Beispiel die rechnen wir immer noch nach dem alten Tarif ab, weil die ganze Umstellung noch nicht gemacht.