The definition of ‘value chain’ depicts the stages of production as an ordered series of activities. These activities create values, consume resources and are linked to one another in processes. According to the approach taken by Michael E. Porter¹, ‘Every firm is a collection of activities that are performed to design, produce, market, deliver, and support its product. All of these activities can be represented using a value chain.’ Another definition describes the value (adding) chain as ‘the stages of the transformation process that a product or service passes through, from starting materials to final use.’² Value added is the difference between the income that the product generates and the resources employed.

To be specific, this means that the value chain is represented by the sum of all values added (margin) of each individual market participant. All market participants who wish to participate in a value chain together make up the value chain system of an industry. If this is applied to our industry, we must consider the specific situation of the market participants, ‘industry, dental lab, dental practice and patient.’ All those involved are part of the value chain. In the past, industry generated its value added by manufacturing consumables or equipment for the dental technician or dentist, the dental technician generated his value added by making traditional dental restorations and the dentist generated his value added by rendering services for patients. The chain has changed more and more over the past 20–30 years, mainly due to the introduction of digital technologies. The following outline presents selected developments based on use of digital technologies, plus a future-oriented project for the integration of total prosthetics into digital technology.

**Analogue meets digital (change in occupation profiles)**

The whole field of digital technologies in dentistry has now become so extensive that not all aspects can be covered in this article. For example, digital technology has an impact on the following.

**The profile of a dental technician’s occupation, which is no longer a ‘plaster room’ job but rather a computer workstation position. As a result, however, the requirements change for candidates because the modern-day ‘skilled trade’ calls for future applicants to be interested in**
special digital technologies

computer aided design (CAD) for crowns, bridges, telescopes, abutments, etc and the programming of milling strategies for transforming the CAD design into an end product that is made by subtractive or additive processes. It is advisable and essential to integrate such requirements into dental technician training at an early stage.

The rendering of dentistry services is calling for increasing use of state-of-the-art digital instruments and methods. In future, a dentist will not only make a diagnosis but chiefly focus on treatment preparation, surgery and the insertion of a dental restoration (conservative or prosthetic). The other activities will be replaced by digital work processes.

There would probably have not been any change in the value chain that had applied for decades (see Fig. 1) if companies like Sirona had not introduced the first digital technologies to dental practices and dental labs in the 1980s. And even though the concept of the shift in value added was already an integral part of the system, initially only work steps and work processes in the dental lab were facilitated, speeded up and thus made more efficient in implementation at the beginning of this digital evolution, by using scanners and CAD/CAM milling machines. Only in a subsequent step were other market participants included, e.g. milling centres in Germany and abroad or also industrial companies that want to participate in the value added (Figs. 2 & 3).

Digitisation—an opportunity for the dental lab?

For a long time now, innovative and marketing-oriented dental labs have recognised the advantages of digitisation and been benefiting from their timely entry to the world of CAD/CAM. Their wide range of services covers the entire dental technology portfolio with modern, state-of-the-art framework materials and veneering materials. Standard restorations in particular, such as crowns and bridges are made by CAD/CAM—nowadays that is already state of the art.

But what impact have these change processes had in the dental lab? The fact is that there has been a shift in the focuses of activity in in-house production towards more services in the digital

Role of market participants in the value adding process, NOT INCLUDING digital steps taking a precious metal-based crown as an example

![Fig. 2. Basic model of market participants in the value adding process, not including digital dental technology.](image-url)
planning and coordination process and the process chain has been minimised. In terms of quality not much has changed, even though it may have been expected. Without doubt, material quality is perceived by the patient only in terms of shade (from gold to white) and the fit/security of a dental restoration is still dependent on the job instructions that have been received from the dental practice. Process quantity has seen a major change—nowadays only half of the original dental lab processes are necessary in the lab in order to produce a functional, highly aesthetic dental restoration. Although in economic terms it means high capital investment costs for the dental lab owner, it also means that, depending on the amortisation period and the quantities to be made, he is able to make competitive prices when faced with market participants who attempt to penetrate the market by price dumping.

These days, the dental lab is—more than ever—a service provider for the dental practice and less and less a skilled trade. That naturally involves risks for the skilled occupation, but it also offers substantial opportunities. A dental lab owner can highlight his locational advantage and provide his special services and cooperation in a spirit of partnership.

What type of dental lab are you? Do you rank among the dental labs that are still highly characterised by craftsmanship? Are you extremely uncertain and waiting to see what happens or do you lack the required knowledge of economics or marketing to also embark on the path of digitalisation? The fact is that anyone who fails to have an open mind about digital technology will no longer have a major player role among the dental labs.
The more dental practices invest in digital workflow and exchange relevant data, the more dental labs have to adapt and serve it technologically. It is still the responsibility of dental labs to support the dentist, and hence the patient, by providing optimal process chains. That is why dental labs should regard digitisation as an opportunity.

_From stand-alone solutions to value chains_

At the beginning of the digital dental world there were stand-alone solutions, single work steps, but nowadays there is more and more consideration of complex dental lab processes that can be implemented on a totally digital basis. It all started with implant navigation, digital function diagnostics, and the production of aesthetic dental restorations in the form of crowns and bridges, and nowadays these have already become mainstream, so to speak, in an innovative, modern-day dental lab. The next step in a dental world that is becoming increasingly digital is advancement towards the consideration of entire value chains—including the process of making full dentures.

_Backward planning for full dentures—the digital value adding process in reverse!

While in the past the introduction of digital technologies chiefly aimed at indication-related solutions for individual work steps, the focus of digital dental technologies is now on entire value adding processes. One of the last groups of topics and areas of indications, which, in digital terms, has so far only been dealt with in passing, is total prosthetics. Here in particular, though, there are innovative digital approaches that will simplify and speed up production. This is where pioneer-
After all, total prosthetics does not merit the reputation of being an 'unloved child'. For dentists and dental technicians it still does not have the same level of importance as other prosthetic restorations. But why? It is certainly not due to the fact that patients are so difficult, or total prosthetics generally is so unattractive to dentists and dental technicians. On the contrary. Production of a precision-fit, functional and aesthetic prosthesis is often a major challenge to dentists and dental technicians. Especially because with edentulous patients important information is frequently missing to be able to achieve an optimal reconstruction of the jaw and mouth. The main reason is rather that the dentist's and dental technician's services to be rendered for a full denture are both extensive and elaborate and the fee chargeable for the service cannot cover the costs incurred. In Germany, between 300,000 and 400,000 full dentures are still being made every year.

And according to expert opinion, the figure will tend to remain constant in years to come owing to a longer life expectancy and sociodemographic change. With an average total fee rate of approx. €1,000–€1,400 per full denture this market segment has a volume of over €300 million—and that only applies to Germany. Consequently, total prosthetics still ranks as one of the most important areas of prosthetics.

The complexity of today's production process for a full denture is illustrated by the following flow chart.

Production of a conventional prosthesis is currently based on complex interaction between the dentist, dental technician and patient. In an idealised process flow, there are at least five appointments for the patient and dentist, which can take several days or even a few weeks. From the very first appointment the work starts to be dispatched, from the first impression, functional impression and occlusal record to the first wax model, until, after much to and fro between the dental practice and the dental lab, the final denture can be fitted in the last appointment. The dentist's net treatment time in the chair can then total about 2.5 hours. Quite often another one to two more appointments are required. Per appointment there is a calculated preparation and follow-up time of at least 5 minutes so if there are five appointments another 25 minutes have to be added on. Consequently, dental practice time soon totals 3 hours or more for a full denture.

At the dental lab end, the level of complexity is even higher. From initial model impression taking
to final completion the dental lab can expect to have dental lab work amounting to 6–8 hours. This does not include pick-up and delivery times for commuting between the dental lab and the dental practice. Even after denture incorporation there is often rework, which is time-consuming and not included in the service fee.

The conventional workflow (Fig. 5) for making a full denture therefore positively cries out for an approach to address the last bulwark of the conventional dental process chain and make a digital solution available.

The future of the full denture is digital

That is definite. Although nowadays there are ways of simplifying individual work steps with a scanner and a CAD/CAM milling machine (prosthesis baseplate or basing arches made from industrially prefabricated blanks), consideration of the process chain as a whole has so far been missing. This is the approach adopted in the following illustrated solution with a full denture based on completely digital development and production. The entire solution concept is based on the principle of backward planning. In real terms this means that a full denture completed by a master craftsman is customised to suit the patient’s oral situation, with just one appointment! Very soon the production of a full denture will take place in a fully digital process—from digital impression taking to production, completely devoid of dust and plaster. Unfortunately the digital scanning systems available at present are not yet able to provide the option of comprehensive collection of oral situation information in a single appointment, but it is definitely only a matter of time. Until then the jaw relation, palate, centric relation and aesthetics will be recorded by analogue means and then transferred to the digital system. By this method, all the data for making the prosthesis later is collected in just one appointment.

The process is followed by comparing the digital data with a prosthesis database, selecting the appropriate milling blanks with previously polymerised dental arches, and the modelling of the gums, which vary from patient to patient. After transferring it to the CAM module all that has to be done is mill the respective maxillary/mandibular pair. That is followed by finalisation in the dental lab.
This new future-oriented method called Baltic Denture System uses digital technologies to make the production of a full denture economically profitable again for the dental practice and the dental lab, for the first time in years. Despite digitisation, market participants remain the same and the value adding process takes place within the familiar, implemented structures.

_Digital technology as an option for additional business_

With the aforementioned method of production and by focusing on a small number of analogue processes in the dental lab there is more scope for new lines of business for dental labs. The dental lab of the future will no doubt regard itself increasingly as a partner and service unit for its dentist and be capable of taking ‘troublesome’ issues off his hands. In addition, the dental lab can manage the data stream for its client to ensure optimal results. Another field of activity that presents itself as a result of digital techniques is that of dental aesthetics! One example is the concept of lächeln2go (smile to go), which, with its volunteers, first developed the concept of dental aesthetics as a new line of business. What is impressive is the use of a two-dimensional aesthetics check that makes it easy to record dental status and aesthetic deficits.

_Conclusion_

It remains to be seen who the winners and losers of increasing digitisation will be. The fact is that we are not yet at the end of optimal digital workflow. It is still important to modernise and develop digital processes. However, the opportunities are quite clearly in the majority, and due to optimisation in the process chain the resulting work has a higher level of precision achieved in a shorter amount of time. This means firstly that thanks to the declining proportion of expenditure accounted for by staff costs per prosthesis it is also becoming possible to increasingly internationalise German dental restoration work. Secondly, scope is being created for new lines of business such as dental aesthetics. The patient too benefits from digital production, which also saves time for him or her. Owing to the use of digital technologies and optimisation of value chains the profitability of hitherto unattractive work is increasing again for the dentist and dental technician. What is more, in this way scope is created for additional service offerings, which in turn creates potential for additional business and income.

_In spite of all the digitisation and value chain optimisation one must not forget that, despite everything, direct contact between the dentist, dental technician and patient is still crucial and important for the outcome: aesthetic and functional dental restoration about which the patient is not only satisfied but also enthusiastic in everyday life._

_References_