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digital

international magazine of digital dentistry

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and I want women to actively shape it"

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Dr Scott D. Ganz

Editor-in-Chief

Fast, faster, fastest...

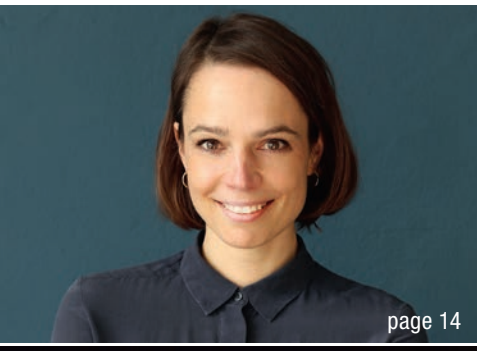
It is difficult to believe that at one time clinicians lectured using 35 mm slides in a Kodak Carousel projector, first using one screen, then two projectors and two screens, and then some clinicians would use three projectors and three screens, all with static images taken with an analogue camera. Of course, this all changed when the graphical user interface became available with the Windows operating system and software like Microsoft PowerPoint was introduced. The problem then became how to move the analogue slides to digital. Many of us either used a service bureau or bought a dedicated slide scanner to digitise the 35 mm slides. For those of us fortunate enough to have one of the first laptop computers, we could take the hundreds of 35 mm slides imported into PowerPoint and leave the slide carousels at home! This was certainly not a fast process for most, but we were so impressed with the imagery that speed was not an issue.

At the beginning, when the practice of dentistry began to go digital, we were all amazed when objects appeared on a computer screen which could be rotated, sized and enlarged for better viewing. Of course, the technology was not always fast, and the images on the screen may not have reacted with great speed, but it was fascinating! Many clinicians started out with an intra-oral digital camera which could be used to capture images of patients' oral cavities in the hopes of educating patients about their oral condition. We could even create physical prints from the intra-oral screenshots and then technology continued to evolve with the introduction of intra-oral scanners which would capture 3D images of teeth and adjacent structures. These first intra-oral scanners introduced clinicians to the use of digital technology in dentistry—a major advance for certain! Computed tomography has been used for dental applications since the mid-1980s, but did not reach mainstream US until after the introduction of CBCT scans, starting after the turn of the century. We could then take data from the intra-oral scanner and merge that data with the data set from the CBCT scan to relate the placement of implants to the actual position of the planned restoration, and we could take the next step to export the final implant plan for CAD/CAM or 3D-printing a surgical guide.

All these innovations have taken years for clinicians to embrace, and we are still at the tip of the iceberg in terms of global use of technology. While this is happening, most of the marketing strategies have been to promote the fastest intra-oral scanner or the fastest 3D printer or immediate loading of implants to achieve faster treatment outcomes. A word of caution: digital dentistry is dependent on sound principles of restorative and surgical dentistry, so although fast may be important, we should not move so fast that we may lose the foundation of proper diagnosis and treatment planning. Sometimes, it is OK if a scan takes 30 seconds longer—if it provides the necessary information to achieve the best treatment outcomes for our patients.

Please take a moment to enjoy this latest edition of digital to learn current concepts and modalities that will enhance your practice of dentistry.

Dr Scott D. Ganz
Editor-in-Chief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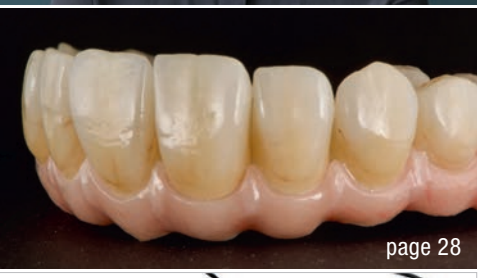
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Dental sales a mixed bag as war and supply difficulties bog down pandemic recovery

By Jeremy Booth, Dental Tribune International

Dental companies may have expected a widespread ebbing away of the SARS-CoV-2 pandemic to bring them out of the financial woods. However, the resulting supply chain crisis has choked the world's ports, and the war in Ukraine has caused consumer price indexes and inflation to soar. Owing to these factors, the first quarter of this year arguably provided a stiffer operating environment than that of two years ago, and economic headwinds appear to have finally caught up with clear aligner therapy.

The first quarter was a challenge for the dental giants Dentsply Sirona, Align Technology, Envista Holdings and the Straumann Group—the latter being the strongest performer during the three-month period ended 31 March.

Sales of clear aligners appeared to be unshakeable at the beginning of the pandemic, but this idea was contradicted by minimal—albeit, symbolic—consecutive dips for the world's largest clear aligner manufacturer. Align had recorded six consecutive quarters of sequential revenue growth prior to the first quarter of this year, when total sales of US$973.2 million (€914.0 million) represented a 5.6% decline compared with the prior quarter.

In a webcast call with analysts, Align Technology President and CEO Joseph Hogan listed three factors that had resulted in a challenging quarter: the continued impact of the COVID-19 pandemic, particularly the strict measures in place in China; a difficult economic environment driven by inflation, waning consumer confidence and supply chain disruptions; and fallout from the war in Ukraine.

Hogan explained that industry data showed a decrease in orthodontic demand. He said: "[The] data from about 700 ortho practices, covering more than 1,000 orthodontists across 1,600 locations in the United States and Canada, showed weakening underlying patient demand trends in the first quarter for both adult and teens and across wires and brackets and clear aligner products."

Hogan added that new patient visits in North America during the period were down by 7.6% year on year.

Dentsply Sirona navigating troubled waters

Dentsply Sirona's revenue for the first quarter was down 6.1% year on year. In the first quarter of 2021, the company topped one billion in sales, and a year later, this had decreased to US$965 million. Operating income of US$93 million represented a decline of 39.5%.

Dentsply Sirona reported preliminary earnings with the US Securities and Exchange Commission and did not submit a Form 10-Q. The company was therefore not in compliance with the listing rules of the Nasdaq stock exchange, where its stock is listed under the XRAY ticker symbol, and was given a period of 60 days to detail the steps it will take to regain compliance. Dentsply Sirona said in a statement in mid-May that it was unable to file its Form 10-Q owing to a pending investigation into its use of incentives to sell products to distributors in the third and fourth quarters of last year. It received a filing of delinquency from Nasdaq.

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These events follow an April leadership reshuffle at the dental giant that included the unceremonious dismissal of Donald Casey as board member and CEO of the company and the appointment of John Groetelaars as interim CEO.

Groetelaars said that it had been a challenging quarter, ending with a disappointing result. He said that US sales had been weaker than in the prior quarters and that COVID-19 restrictions in China, supply chain issues and disruptions resulting from the war in Ukraine were hampering the manufacturer. Dentsply Sirona earns roughly 5% of its revenue in China.

Barbara Bodem, the company's interim chief financial officer, noted that currency exchange rates and increased investments in research and development had contributed to the drop in operating income. "We attribute approximately 60% of the year-over-year decline to the transitory macro challenges of foreign exchange, inflationary pressures, and the impact of COVID in China," Bodem told analysts, noting that earnings per share for the first quarter were US$0.52 versus US$0.72 in the comparable period last year.

"Dental companies faced a difficult economic environment during the first quarter of this year."

Straumann Group outperforms

Straumann reported revenue of CHF589 million (€573 million), a year-on-year increase of more than 25% compared with the CHF469 million that it banked for the same period last year. Straumann's sales increased by double digits (on an organic basis) in all regions where it operates, and its sales grew most quickly in the Latin America region.

In Latin America, Straumann's sales for the quarter increased by 56.1% to reach CHF39.3 million. Sales of CHF267.2 million for the Europe, Middle East and Africa region represented an increase of 24.7%, and those for North America—at CHF170.1 million—were up by 23.2%. Sales for the Asia Pacific region amounted to CHF112.3 million, and this represented Straumann's narrowest regional growth margin of 21.7%.

Straumann said in its results that patient volumes had remained strong in most countries during the three-month period, except in China, where local lockdowns to contain the spread of SARS-CoV-2 had interrupted patient flow.

CEO Guillaume Daniellot commented that digital solutions, led by intra-oral scanners, had helped sales, and the company attributed some of its success during the quarter to a strong performance from its dental support organisation business in North America and to sales of premium dental implants in the region. In Latin America, orthodontic sales grew rapidly and sales of the Straumann Virtuo Vivo intra-oral scanner drove revenue growth.

Sales growth in China was constrained by COVID-19 lockdowns, Straumann said, but the impact of this had been partially compensated for by strong sales in fellow Asia Pacific markets Japan and Australia and expansion in India. "Across the region, premium implants and orthodontics contributed strongly to the overall performance," the company said.

Envista leads way to differentiated portfolio and remains upbeat on dental

During the quarter, Envista further aligned its portfolio with faster-growing segments of the dental industry. In January, it completed the sale of its KaVo treatment unit and instrument business to Planmeca and announced that it would purchase Carestream Dental's intra-oral scanner business.

The company's revenue from the first quarter amounted to US$631.4 million and represented a year-on-year increase of 5.4% in core sales growth. Sales of specialty products and technologies were US$397.1 million, compared with US$366.5 million in the first quarter of last year, and sales of dental equipment and consumables decreased to US$234.3 million from US$246.1 million. Operating profit for these two segments during the period showed little year-on-year change, being US$70.3 million and US$45.5 million, respectively.

CEO Amir Aghdaei said in Envista's earnings announcement that the company had performed well in what had been a "challenging macro environment" and that it had made progress towards its goal of transforming its portfolio and building a strategically differentiated dental company. "With the closing of the acquisition of Carestream Dental's intra-oral scanner business, we have now added a suite of world-class scanners and software solutions that further differentiate our portfolio and support our vision of digitising, personalising, and democratising dental care," Aghdaei said.

Signalling the company's ongoing optimism about the dental sector, Envista announced in May that it would acquire Osteogenics Biomedical, a leader in the development of regenerative solutions for periodontists, oral and maxillofacial surgeons, and clinicians involved in implant dentistry. The transaction is expected to close in the third quarter of this year.

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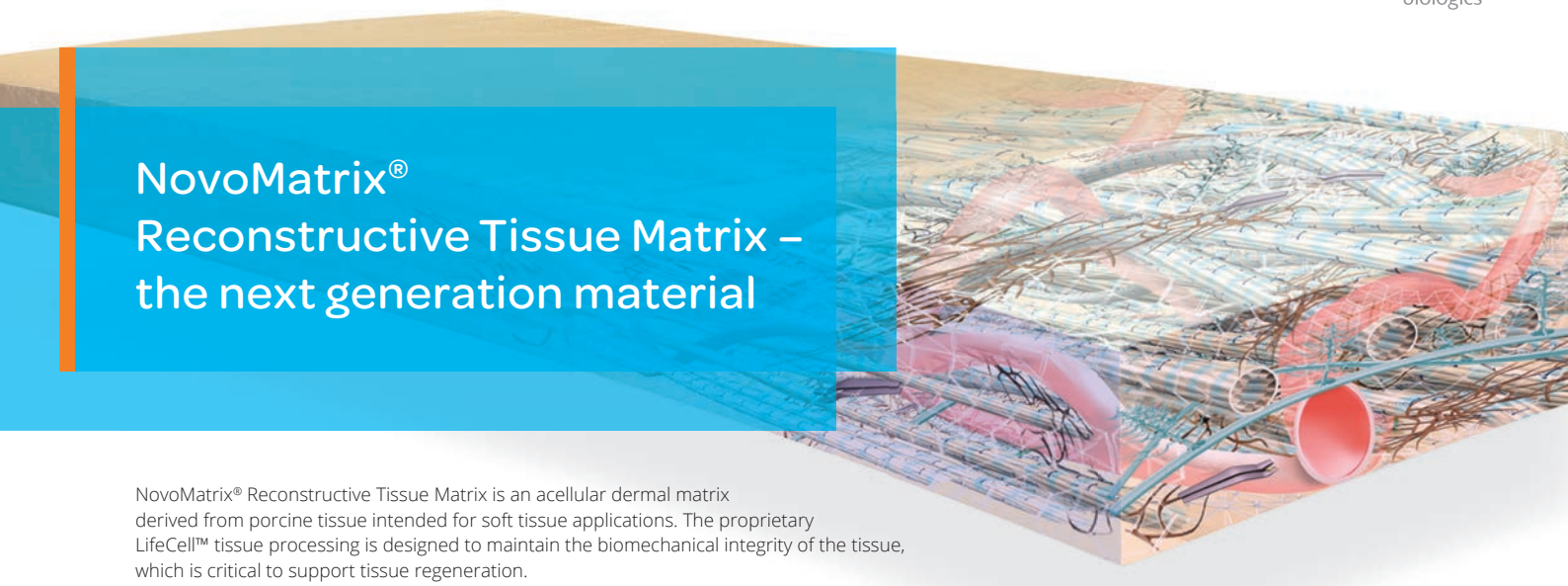

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GDC reveals continuing impact of COVID-19 on UK dentistry

By Brendan Day, Dental Tribune International

As the statutory regulator for all dental professionals across the UK, the General Dental Council's (GDC's) main aim is to maximise patient safety and promote confidence in the provision of dental services. Recently, the GDC published a pair of surveys that measured the impact of COVID-19 in 2021 on dentists and dental patients, respectively. The findings of these surveys indicate that, though UK dentistry has begun to return to normal, major hurdles still exist across a number of areas.

The GDC commenced research on the impacts of COVID-19 on oral health and dentistry back in August 2020, the key findings of which it published in December that same year. This second set of surveys was conducted in the same period in 2021 and, according to the regulator, aimed to capture how the perceptions of dental professionals and the general public towards dentistry had continued to evolve throughout the pandemic.

To better understand the impact of COVID-19 on dental professionals in 2021, the GDC commissioned Pye Tait Consulting to conduct an online survey of 2,168 respondents, six focus groups with 39 total participants and five further in-depth phone interviews. One of the key findings of its research was that the well-being of UK dental professionals is markedly lower than that of the general population. Based on dental professionals' rating of their happiness on a scale of 0 (not at all happy) to 10 (completely happy), the mean average happiness score was found to be 5.2. The average anxiety score on a scale of 0 (not at all anxious) to 10 (completely anxious) was 5.6. In comparison, a survey conducted by the Office of National Statistics found that the average happiness score in the UK in 2020/2021 was 7.31 and the average anxiety score was just 3.31.

From a financial perspective, the effects of the pandemic continued to be felt by many dental practices: 69% of respondents said that their income had decreased compared with pre-pandemic levels, significantly higher proportions of National Health Service or mixed public–private dental practices reporting reduced incomes than

those working purely in private dentistry (78% compared with 63%). In addition, approximately 35% stated that they believed their income would remain lower than pre-pandemic levels over the next year.

Patients continue to face issues of access

For a snapshot of the general public's attitudes towards COVID-19 and its impact on dentistry, the GDC commissioned the Community Research company to carry out independent research. An online survey that explored attitudes about patient safety and dental visit frequency, among others, was filled out by 2,389 members of the public, spread across England, Wales, Scotland and Northern Ireland.

Some of the findings reinforced the widespread notion that UK dentistry is dealing with challenges at a systemic level in providing adequate care for patients. Though most individuals who wanted a dental appointment had been able to secure one, 22% reported being unable to book an appointment since August 2020. A higher proportion of young people and individuals of Asian or Black ethnic backgrounds stated that they had experienced difficulties in accessing dental services, indicating that the pandemic had continued to exacerbate oral health inequalities in the UK. Meanwhile, around one-quarter of respondents said that they were still hesitant about visiting a dental practice owing to concerns about COVID-19.

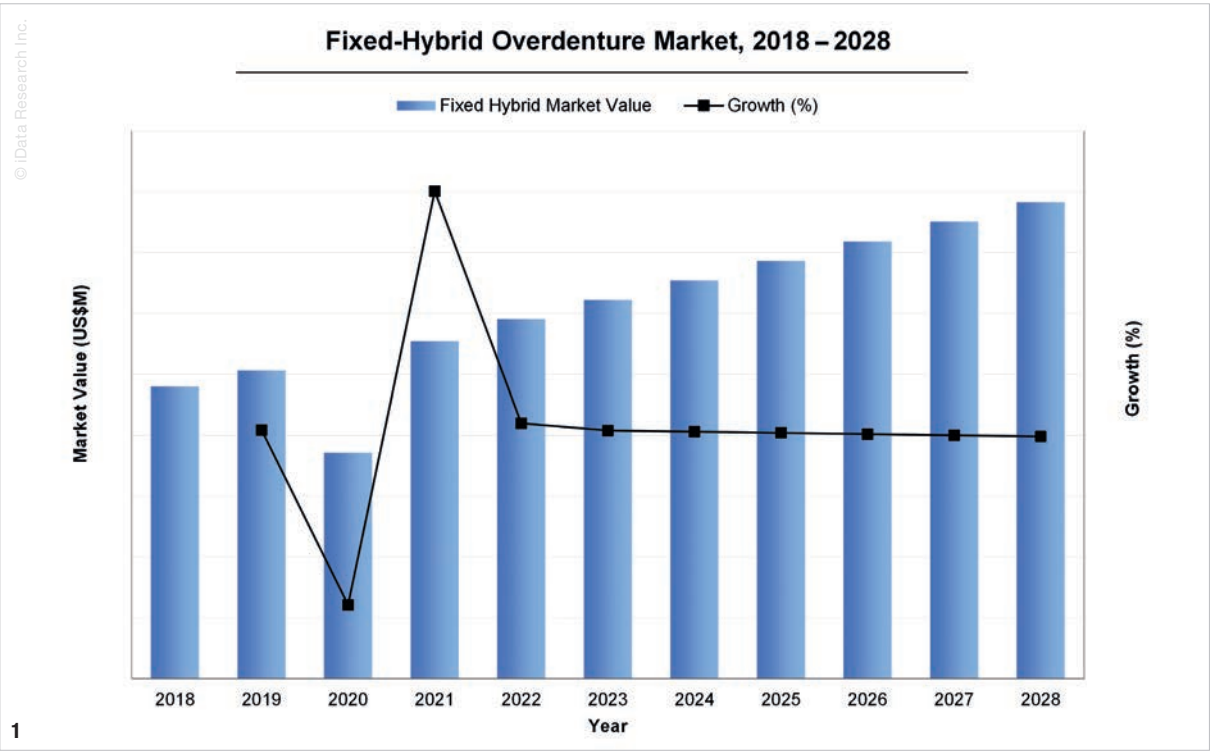
> "Dental professionals continue to rise to challenges posted by the pandemic [...]"

"Dental professionals continue to rise to the extraordinary challenges posed by the pandemic, but these findings point towards a system being overstretched," said Stefan Czerniawski, executive director of strategy at the GDC, in a press release.

He added: "Many of the most pressing and wide-reaching challenges highlighted in this research, such as access to services, health inequalities and pressure on professionals, will require attention and effort from everyone right across dentistry. While some of these are areas outside of the GDC's direct control, we will use this evidence to inform all our work and share the insights with our partners to support those broader efforts to address these problems."

Preferences for fixed restorations and resulting impact on the US and European overdenture markets

Daniel Sussman and Dr Kamran Zamanian, Canada



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In recent years, patient preferences for fixed restorations have driven significant growth in both the US and European fixed-hybrid overdenture markets. This trend is particularly pronounced in the US, where patient awareness has also been a significant factor in recent years. Though it was slowed momentarily by the COVID-19 pandemic, this market has made a full recovery and is set to experience single-digit growth moving forward.

Fixed-hybrid overdentures are full-arch restorations that use an implant bar into which the dentist screws the denture prosthesis and, therefore, they cannot be removed by the patient. This makes them similar to natural teeth and eliminates much of the hassle of regular maintenance. As a result, the proportion of patients seeking a fixed-hybrid restoration has soared across the US and Europe despite their premium price tag. During the pandemic, there has been a rise in demand for more affordable options such as implant-supported overdentures, but the fixed-hybrid overdenture market has now recovered and, as can be seen in Figure 1, is set to grow steadily in the coming years.

Fixed attachments gaining ground

The growth of the fixed-hybrid overdenture market as well as that of the total overdenture market has had a positive impact on both implant bar and attachment markets. In 2016, Zest Dental Solutions launched its Locator F-Tx fixed attachment system. This system operates as an alternative to screws and cement, and has created significant value in the attachment market. Zest's fixed attachment system has experienced significant growth, as the system has been used to secure an increasing number of fixed-hybrid overdentures. Whereas Zest Dental Solutions' Locator F-Tx currently dominates the fixed attachment

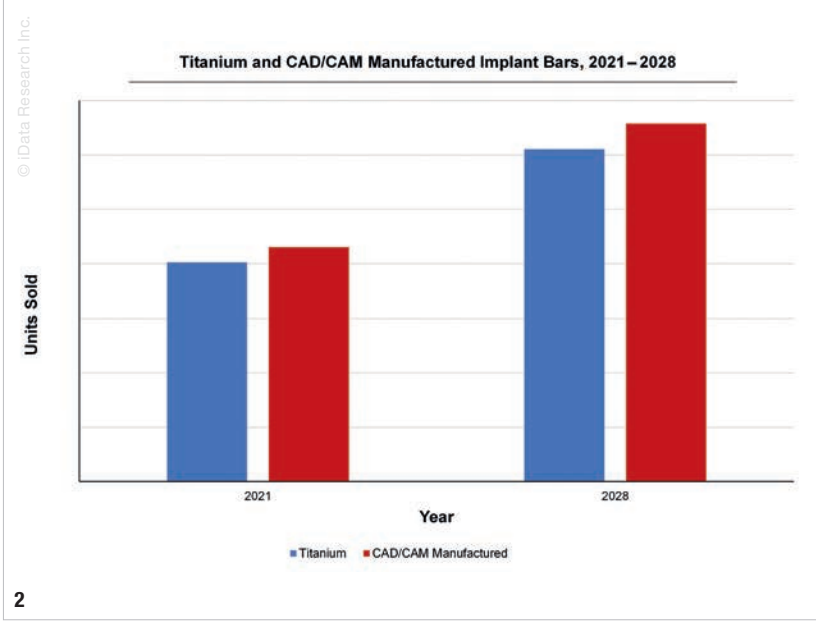
market, other minor competitors exist, such as the Smileloc system. Naturally, the fixed attachment market not only benefits from a steadily increasing rate of adoption but also from being tied to the fastest growing segment within the overdenture market.

A shifting landscape for the implant bar market

Like the attachment market, the implant bar market is also undergoing substantial changes that will affect it in both the short and long term. The first such change relates to the market's competitive landscape. The implant bar market can be broken down into implant bars manufactured by dental laboratories and those manufactured in independent milling facilities. Traditionally, there was a near-even split between dental laboratories and milling facilities in the US; however, dental laboratories command a significantly higher share of the market in Europe, particularly in Italy, Spain and Portugal. Recently, the growing use of CAD/CAM technology has increased efficiency in the milling process and decreased the cost. Hence, smaller dental laboratories are now able to produce their own implant bars inexpensively, substantially increasing their share of the implant bar market.

The competition between milling facilities and dental laboratories, in addition to the increased efficiency and cost savings of CAD/CAM technology, have combined to place downward pressure on implant bar prices across the US and Europe. As CAD/CAM technology becomes more accessible, an increasing number of dental laboratories have begun in-house manufacturing of implant bars. The increased efficiency of this process has caused the cost per implant bar to decrease. Whereas dental laboratories and CAD/CAM milling facilities are interested in maintaining their profit margins, reduced costs present an opportunity to capture greater market share. As a result, the price of implant bars has been decreasing while the use of CAD/CAM technology increases. This is expected to reach a plateau as the implant bar market becomes saturated with CAD/CAM milling. These price reductions also have an impact on the pricing of splinted overdentures such as fixed-hybrid overdentures and removable implant bar overdentures, since the implant bar is a key component of these overdentures.

Another current trend within the implant bar market regards the materials being used in their fabrication. Implant bars in both the US and Europe are primarily fabricated with titanium, cobalt chromium or, occasionally, gold. In the US, the use of titanium has been most popular whereas in Europe, cobalt is used more often. Both titanium and cobalt chromium have benefits. Cobalt has been used in dentistry for decades and is a very strong, biocompatible material with high corrosion resistance. Titanium is also a very strong and corrosion-resistant



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material. Where titanium distinguishes itself, however, is through its lightweight nature, elasticity and superior biocompatibility. In the implant bar market, titanium has been gaining considerable popularity, mostly owing to its biocompatibility. Germany, Scandinavia, Austria, Switzerland and the Benelux region have paved the way in the use of titanium in Europe. Cobalt chromium still commands a significant unit share of the implant bar market in France, the UK, Italy, Spain and Portugal, but titanium is expected to become the dominant implant bar material in these countries over the next decade (Fig. 2).

Closing thoughts

In summary, shifting patient preferences towards fixed-restorations and the widespread adoption of CAD/CAM technology has led to significant changes in the overdenture market. Whereas the future may be uncertain, iData Research forecasts indicate that this market is expected to experience substantial growth over the next five to ten years across Europe and the US. This will be spearheaded by remarkable growth within the fixed-hybrid overdenture, implant bar and fixed attachment markets.

about

Daniel Sussman is a research analyst at iData Research. He develops, writes and models syndicated and custom research projects for various medical device industries. To date, he has published the company's European gastrointestinal endoscopic devices report as well as its US and European dental overdentures series.

Dr Kamran Zamanian is CEO and founding partner of iData Research. He has spent over 20 years working in the market research industry with a dedication to the study of dental implants, dental bone grafting substitutes, prosthetics, as well as other dental devices used in the health of patients all over the globe.

“The future is digital, and I want women not only to participate in the future but also to actively shape it”

An interview with Eva-Maria Meijnen

By Franziska Beier, Dental Tribune International

Eva-Maria Meijnen

Female leaders are still under-represented in many fields, and dentistry is no exception. This situation inspired Dental Tribune International (DTI) to talk to Eva-Maria Meijnen, co-CEO of a growing clear aligner business based in Berlin in Germany. In conversation with DTI, she spoke about what drives her professionally, how diversity can benefit a business, the importance of celebrating women’s achievements more and future endeavours for her company.

Ms Meijnen, could you please tell us about your professional background? What did you do before you became co-CEO at PlusDental?

I have always had a passion for technology and innovation—wanting to understand in detail how things work and how I can help make them work even better. This has been reflected in my academic and professional choices. I have a degree in industrial engineering from the Karlsruhe Institute of Technology. After graduating, I began my professional career at Siemens introducing new manufacturing and supply chain concepts following the lean management approach. I absolutely loved its rather simple but important core principle: always put the customer in the centre and optimise holistically, not at the cost of one party but rather creating a win–win situation. After two years, I joined Porsche Consulting, the expert consultancy on lean management, as a senior consultant in order to gain more experience in different companies and industries. In 2009, I joined engine manufacturer MTU, where I first set up an internal consultancy and then held various management positions.

What sparked your interest in PlusDental?

I believe that technology and digitisation hold immense potential for the healthcare sector in general and for the dental sector in particular—the potential to offer modern

Eva-Maria Meijnen joined PlusDental shortly after it was founded at the end of 2017. She was appointed chief operating officer at the beginning of 2019 and co-CEO in December of the same year.

Eva-Maria Meijnen in the PlusDental office in Berlin. Presently, more than 50,000 patients have received treatment with the company.

and improved treatments at reduced costs to more patients. It was this purpose that I found irresistible and that made me end my corporate career and join a nine-month-old start-up.

I first came across the invisible aligner product through a friend who had returned from working in the US. I immediately noticed that something was different about her. Her demeanour had changed completely; she seemed to have much greater self-confidence and a new charisma. She told me that she had undergone an aligner treatment in the US and that she had felt much more comfortable in her skin ever since. Two things in particular struck me. Firstly, the fact that something as small and barely visible as an aligner can have such an enormous impact on one's life and, secondly, that this fantastic product was hardly known in Germany and was affordable for even fewer people.

Weeks later, I met Lukas Brosseder, a good friend of mine and a serial entrepreneur. He told me about this new company he was going to found, a company that had the vision to bring the invisible aligner product and a new digital treatment concept to Germany. So, it's probably no surprise that I wanted to be part of this journey.

"I care about creating a company that shapes the future of dentistry."

You share the leadership position with two other colleagues. What is your specific area of responsibilities within the company?
We are all co-CEOs and, whereas each one of us has his or her own field of responsibility, we take all important and strategic decisions together.

I am responsible for our medical team, our operations, finance, customer relations, sales and human resources. One milestone of which I am particularly proud is the setting up of our own production of aligners and retainers in our Berlin dental laboratory. From our treatment plans to our products, everything is 100% made in Germany.

You are aiming to reach unicorn status for PlusDental this year, which would make you the first woman in Germany to co-lead a company with such a status.

Brand ambassador Bruce Darnell (left) and Eva-Maria Meijnen in the PlusDental flagship clinic in Berlin.

Please tell us more about this endeavour. What drives you?
Change is amazing—this is exactly what drives me personally and PlusDental as a company. Our goal is not only to digitise and modernise dentistry, but also, and above all, to democratise it. We want more people to have access to innovative and affordable dentistry that meets the highest medical standards. I'm really passionate about empowering people to change the things that they are not happy with.

I don't personally care about the evaluation of my company and even less about unicorn status. I care about creating a company that shapes the future of dentistry. A relevant and large company that has the scale to make a significant difference.

You have been accused of exploiting your role as a female leader for PR purposes. How did you respond to that and how can we move towards a culture where women's achievements are celebrated more?
Contrary to a LinkedIn comment accusing my leadership claim of being femwashing, I was promoted to the position of co-CEO purely on the basis of my hard work and the results I delivered. Instead of discussing semantics, it is vital to focus on the really important issues, such as supporting as well as empowering more women on their professional journeys.

Fifty per cent of the population is female; however, we are heavily under-represented in all areas where important decisions are made and our future is shaped. I believe it is time to change that. We should celebrate every woman who makes it to the top and make sure that many others will follow in the same path.

How do you evaluate the importance of role models?
Role models are both an important source of inspiration and proof of what's possible. I think it's very important to have role models that speak to you in different areas of life. It can be someone from your immediate environment, a scientist, an entrepreneur or a fictional character from a book, show or movie. Role models can inspire and empower girls and young women greatly by showing them that the sky's the limit.

In your opinion, how can gender equality benefit a company or other structures?
I believe that diversity in any form is beneficial for a company. When different backgrounds and perspectives come together, it automatically forces you to look at things from a different point of view and to step outside your comfort zone. This is the best foundation for being truly creative and successful, as in this way you gain new insights and are much more willing to challenge the status quo. Also, you are much less prone to strict group thinking. I have noticed this in my own teams as the best ideas have come from diverse teams.

In addition, there's another interesting and noticeable side effect. A company that's genuinely diverse has a strong pull effect as it automatically attracts diverse employees, making it a key factor in the competition for the best talents. Great business ideas can be duplicated to a certain extent, but great teams cannot.

I am proud that we have such a diverse team composed of members coming from more than 50 different nations. Fifty per cent of our employees are female, and this is true at all leadership levels.

Based on your own experiences, what do we need to change in society in order to enable more women to reach the top?
It is never just one thing when it comes to changing society. A key aspect for me is education. Already as children we often encounter outdated stereotypes like "technology and maths are only for boys". Let's inspire and motivate all children alike to try out new things without any limitations. My parents have always encouraged me and taught me to remain curious, open-minded and brave. They brought me up having the awareness that everything is possible. The future is digital, and I want women not only to participate in the future but also to actively shape it. To this end, they need to believe and be confident that they can do anything they set their minds on.

I also believe that schools play a decisive role. Young girls should be given the chance to try out different things from an early age, and we should use formats that go beyond the classic way of teaching subjects such as maths. Technology-related subjects such as coding, machine learning and environmental technology should be included more often into the regular school schedule. Coding, for instance, is easy to learn, and it fosters analytical thinking in a manner that is playful and low threshold.

In addition to encouraging new approaches in school education, it's very important to promote entrepreneurship in general and inspire young women to help shape the technology scene and the digital future within their own companies. This is the case with "Makers of Tomorrow", an initiative of the German Chancellery to encourage and inspire university students to start their own businesses. It's in an online course format and consists of ten master classes given by different start-up CEOs and their founders. I'm very proud to be part of this project by providing a master class.

Besides education, I have seen many talented women in my generation stepping down when they started a family. They took over the majority of family and care work and reduced their working hours for years, even after their parental leave was over. It is, of course, each person's personal decision how to combine career and family planning. My husband and I decided that we will share everything 50/50. We both continued working full-time and took care of our home and family together. I would not have been able to follow my career plans without equally sharing all responsibilities with my husband. From my experience, this set-up is still an exception.

> "The focus for us remains on further digitising high-quality dentistry and making it accessible to even more people."

The tooth models that serve as the basis for manufacturing each step of the aligner treatment are 3D-printed. *(All images: © PlusDental)*

What are your ideas and plans for PlusDental and the oral healthcare sector in the future?
The focus for us remains on further digitising high-quality dentistry and making it accessible to even more people. Accordingly, we want to continue to constantly improve our processes without compromising accuracy and quality. We are also considering expanding our current medical services to include new dental areas such as more advanced aligner treatments and adding new products to our portfolio such as whitening, prophylaxis and artificial dentition. Furthermore, we want to strengthen our presence in our current markets and also internationally. No matter where we are, we want to offer modern dentistry that people can afford.

Editorial note: This interview was conducted before it was announced on 20 May that PlusDental is to become part of the Straumann Group.

"At age 37, CEREC advances the restorative capabilities of dentists as never before"

An interview with Prof. Werner H. Mörmann and Dr Cord F. Stähler

By Jeremy Booth, Dental Tribune International

Fig. 1: CEREC pioneer Prof. Werner H. Mörmann. **Fig. 2:** Dr Cord F. Stähler is chief technology officer at Dentsply Sirona. *(Images: © Dentsply Sirona)*

CEREC was launched in 1985 as the first complete CAD/CAM system for the fabrication of dental restorations. Astoundingly, nearly four decades later, CEREC remains the sole solution of its kind and is used by dentists the world over, including by the youngest professionals, who would be hard pressed to swap their iPads for Macintosh XIs. CEREC founders, Prof. Werner H. Mörmann and electrical engineer Dr Marco Brandestini, unveiled the system to a bewildered profession, and many dentists insisted that digital technology had no place in oral healthcare. Dentsply Sirona, however, quickly recognised its potential, partnered with the inventors and became instrumental in the system's development. Dental Tribune International had the honour of speaking with Prof. Mörmann, who recently celebrated his 80th birthday, and with Dr Cord F. Stähler, chief technology officer at Dentsply Sirona, about the history and future of the one-and-only CEREC.

Thank you for speaking with us, Prof. Mörmann. Could you tell us how you came up with the idea for CEREC?

Prof. Mörmann: In 1979, a very intense discussion in dentistry arose about a possible health risk from the mercury component of amalgam, the then standard material for treating carious defects in molar teeth. Dentists began to systematically replace amalgam fillings with composites, and patients liked the more aesthetic tooth-coloured fillings. However, these caused new problems: the large resin-based posterior fillings leaked from the beginning because of polymerisation shrinkage, causing pain and secondary caries. As a lecturer and researcher, I felt compelled to seek a solution.

The solution was to have the filling fabricated quickly outside the mouth and to bond it to the tooth as an inlay. However, conventional inlay procedures using ceramic or metal were laborious and time-consuming, and it was clear that new technology would be needed to solve the problem. Around this time, the accessibility of computers was increasing, and their potential fascinated me. That was when the idea came to me that dentists could produce inlays by themselves using digital technology: 3D-scanning the tooth, for example, and designing the inlay and having it formed quickly from a block of aesthetic material directly in the practice. This brought ceramics to the forefront of interest because the material was very similar to tooth structure physically, biologically and aesthetically. Using ceramics, however, required a completely new manufacturing technique as well as a new clinical concept. The rest is history!

The development of the CEREC system was not quite straightforward. What setbacks did you experience and how were they overcome?

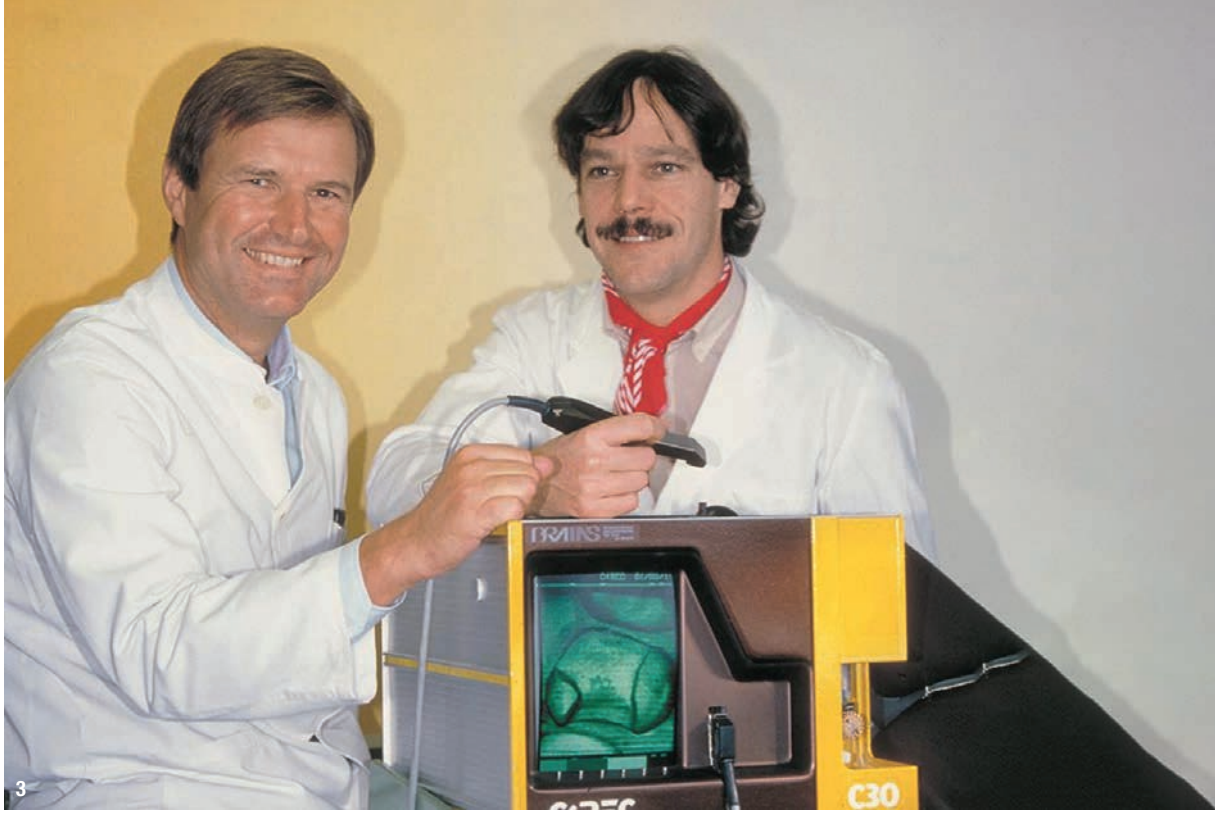

Fig. 3: Prof. Werner H. Mörmann (left) developed the CEREC system in the early 1980s together with electrical engineer and close friend, Dr Marco Brandestini.

Prof. Mörmann: I had a technical solution in mind that would integrate data acquisition, design and form grinding into a small mobile unit. The solution needed a monitor and had to be a practical device that could be used chairside by the dentist. Dr Marco Brandestini, an electrical engineer and a good friend of mine, was also enthusiastic about the idea and saw it as a technical challenge for himself. Our first functional model of a form grinding machine actually self-destructed when the grinder sank into the ceramic!

The solution was to use cylindrical plunge grinding along the mesiodistal inlay axis with a diamond-coated grinding wheel and a water turbine as the drive. This worked quickly at the chairside, but the occlusal surface was flat and dentists had to shape the fissures and cusps manually by themselves after bonding. I am extremely pleased that inlays made in this way still work after 25 years or more. This solution—together with many clinical studies—confirmed that the clinical concept was viable. The full story of the technical and clinical emergence of the CEREC method is rather long, but those who are interested can download it free of charge from moermanncerecstory.com, in English or German.

Dr Stähler, as CTO at Dentsply Sirona you are well versed in all matters relating to CEREC. How important has the system become for the company?
Dr Stähler: Dentsply Sirona and CEREC have been inseparably linked for many years. In 1985, when CEREC was launched, digitalisation in dentistry was still in its infancy, and scepticism and reservations about it were prevalent.

As a company, however, Dentsply Sirona always believed in this idea and demonstrated its perseverance from the very beginning. Engineers from our company were in constant exchange with Prof. Mörmann and Dr Brandestini, and with CEREC users. Together, the parties continued to develop the system and to set new standards in digital dentistry.

Today, the system is mature, and the quality of the clinical results are unquestionable. CEREC has had a huge impact on us as a company and continues to do so. Digital is now part of our DNA: we think, we act, and we live digitally.

How would you describe the current significance of CEREC in dentistry?
Dr Stähler: CEREC, as a system, is a fixed force in the market. The all-new CEREC includes Primescan and the CEREC Primemill, and it is now easier for an even wider circle of practitioners to decide how this modern digital technology can be used quickly and economically in individual dental practices.

The individual components of CEREC, including the scan, the software, the milling and grinding machine and the material block, are optimally coordinated to provide a seamless workflow. Digital chairside dentistry is now faster, easier and more reliable than ever before. It has reached a new level of quality, and this provides for a noticeably more comfortable treatment experience for the patient.

The use of 3D scanners is increasing dramatically. Where does the Primescan fit into the CEREC system?
Dr Stähler: We developed intra-oral scanning in the context of CEREC and, by doing so, established a market for the technology. Today, we see the use of intra-oral

Fig. 4: Innovative and fully integrated CEREC system.

scanning and digital impressions growing beyond chairside and encompassing all areas of dental treatment; first and foremost with clear aligners, but also in the daily interaction with laboratories. Here, we see our market-leading and patient-benefiting precision and speed as key advantages. We will continue to drive single-visit dentistry, but we will also use our experience of dozens of years in chairside for all other applications, especially in the cooperation with dental laboratories.

Prof. Mörmann, are you surprised that new applications for CEREC are still being discovered?
Prof. Mörmann: Not at all! I said a few years ago that the intra-oral scanner has the potential to scan the complete oral situation for diagnosis during practically any dental examination. To name just one example, scans can also be done by dental assistants. In any case, as a treatment method, CEREC still offers plenty of scope for further developments. These could relate to any of the steps, including data acquisition, form grinding, milling technology and materials.

While we are on the topic of new developments, Dr Stähler, what can you tell us about the latest upgrades of the Connect and CEREC software?
Dr Stähler: The latest upgrade of the Connect and CEREC software is upgrade 5.2, and it has provided users with new functionalities and even better performance. Patient communication has also been improved through a new visualisation step in the model phase. It is now possible to view the model directly without restoration selection. Primescan users also benefit from these updates, and new firmware makes the intra-oral scanner faster and extremely stable while giving users access to new workflows and even better usability.

How do these developments benefit dentists?
Dr Stähler: Owing to its improved firmware, Primescan can now generate more 3D data points per second than ever before. With software generation 5.2, the scanning speed and scan stability have doubled. For clinicians working with Primescan in their practices, these improvements in firm- and software result in more efficient workflows and even greater reliability and they also provide a more comfortable patient experience.

CEREC is the best example of Dentsply Sirona's pioneering of digital dentistry. Using CEREC, we are building a digital platform that brings together all stakeholders and devices and the intention is that new technologies and existing equipment can be seamlessly integrated into the workflow. By doing that, we can help dentists to focus on providing patient care and we can give patients a much better and smoother experience.

What drives upgrades to CEREC? Is it advancements in technology or changes in dental treatment and patient preferences?

Prof. Mörmann: Foremost are the expectations of the patient. Whether he or she needs the perfectly aesthetic blending in of a single anterior tooth or a full rehabilitation of the dentition, the patient wants to have the treatment done with efficiency and the results of the restoration need to be pleasing and clinically and aesthetically durable. Upgrades have led to the perfection and expansion of the application of the CEREC method, and the system itself has also benefited from advancements in technology. These developments go hand in hand. For example, I expect that the large number of digital CEREC restoration designs worldwide could be analysed using artificial intelligence in order to develop assistance systems that would further improve restorative work.

Dr Stähler: I agree, and I would add that the driving force behind innovation is the sum of many factors. Dentists and dental technicians wish to treat and care for patients in the best possible way, and our goal is to support them. Our focus on digital technologies has made dental treatment more accurate and more pleasant for patients, and it has resulted in workflows in laboratories being safer, more cost-efficient and more predictable.

Our success in developing solutions that meet the needs of dentists worldwide is the result of a competitive spirit and talented employees who are committed to product innovation and high-quality service and training. Improving clinical outcomes, workflows and patient satisfaction is a driving force in our daily efforts, and we are continually investigating ways in which we can redefine the limits of what is possible. As you see, it is not just about technology; it is also about attitudes and emotions.

What do you think the future holds for digital dentistry and how will CEREC compete with other advancements, such as 3D printing?
Dr Stähler: Digital technologies will always offer benefits. Diagnostics and planning can be implemented in a time-saving manner, and the patient can find out very quickly which treatment options are available and what the results will be. The treatment itself is also faster. The keyword here is single-visit dentistry and, ultimately, this will lead to even greater cost-efficiency for dental practices. The CEREC procedure, which includes digital impressions and chairside manufacturing of restorations, plays an important role in this.

A 3D printer could be a useful addition to the portfolio for use in applications in which milling and grinding machines do not always provide an optimum result—such as in the use of composites. I believe that 3D printing is ready to take centre stage; it is ready to become a part of the daily workflow for clinics and laboratories alike. So, watch this space!

However, CEREC and 3D-printing technology are not mutually exclusive. They complement each other perfectly in digital practices and laboratories. I am certain that 3D printing will be used alongside CEREC for a long time to come and that both technologies will have their specific use cases.

Prof. Mörmann: Anyone who is involved with digital technology knows: never say never. Forty years ago, we would never have dreamed of all the things that are now possible with CEREC. In this respect, as we consider the future, all dental professionals can look forward to being part of a very exciting process of development.

> “Forty years ago, we would never have dreamed of all the things that are now possible with CEREC.”

Finally, Prof. Mörmann, what gives you the most satisfaction as the inventor of CEREC?
Prof. Mörmann: For me, it is the fact that the method, as it is today, is more fascinating than ever. It has increased the enjoyment of restoring teeth, be it with single inlays, onlays, overlays of any form and size, half and full crowns, endocrowns, veneers, anterior and posterior crowns, tabletops, implant crowns, quadrant treatments, three- and four-unit bridges or complex full-mouth rehabilitations. Restorations are automatically generated with individual biogeneric occlusal morphology using habitual bite or virtual functional registration. Drilling templates can be fabricated. To sum up, CEREC provides dentists with a vast choice of high-tech, highly aesthetic ceramic, hybrid ceramic and composite restorative block materials with suitable strength.

Everything runs smoothly, quickly, easily and with high precision: the scanning, the restoration design and the machining. And the result is first fit, at the margins as well as at proximal and occlusal contacts. We are talking about a system that was launched in 1985. To me, this represents an awesome and truly fantastic success, and for this, I would like to thank the developers at Dentsply Sirona! It is wonderful to realise how many colleagues around the world are successfully using CEREC in their practices and providing patients with excellent clinical care. Without a doubt, at age 37, CEREC advances the restorative capabilities of dentists as never before.

Editorial note: The name CEREC is derived from Chairside Economical Restoration of Esthetic Ceramics and also from the initial letters of ceramic reconstruction.

Experiences of and successes achieved with Zolid zirconia

How a dental material developed to become a game-changer—An interview with Falko Noack, Prof. Bogna Stawarczyk & Atsushi Hasegawa

By Amann Girrbach

Fifteen years ago, Amann Girrbach was one of the first companies to manufacture and sell zirconia blanks for the production of dentures. This was followed five years later by the launch of the Zolid brand: for the first time, users were offered CAD/CAM blanks that enabled excellent aesthetic results without requiring complex veneering processes. Since then, the company has continuously developed its materials and manufacturing processes and has gained numerous faithful customers. In this interview, Falko Noack, vice president of research and development at Amann Girrbach; Prof. Bogna Stawarczyk, scientific director of materials science of the outpatient department of dental prosthetics of Ludwig-Maximilians-Universität München in Germany; and Atsushi Hasegawa, owner of the Organ Dental Lab in Chigasaki in Japan, discuss the advantages of zirconia as a dental material, the developments over the past years and possible future challenges.

> "Certainly the most important innovation was Ceramill ZI, our first self-developed zirconia blank."

Mr Noack, you were already interested in zirconia and its applications as a student in the course of your university studies and became more intensely so in the past 15 years in the scope of your work at Amann Girrbach. How were the beginnings, and how have things developed in all these years?

Noack: Even during my studies at university, zirconia appeared to me to offer an ideal alternative to the dental materials that existed at the time. However, issues with verified processing and limited usability constituted strongly limiting factors. When I was given the opportunity after completing my studies to address these issues at Amann Girrbach, I was immediately enthusiastic. The establishment of the zirconia blank production and the application-side supervision of initial verified processing methods, such as copy milling, were highly exciting projects—we were able thereby to generate immensely important basic knowledge. Since its introduction, zirconia has virtually gone through the roof. There is hardly another material that has undergone such amazing development. All issues on the manufacturing side, including the now almost exclusively CAM-based processing, correct sintering management and veneering, are to be considered verifiably resolved. In the aesthetic field too, zirconia has exhibited a steep performance curve and can thus, by virtue of increased translucency and enhanced colour properties, also be used monolithically. The long-term clinical results provide evidence of very good suitability and an excellent survival rate for the greatest variety of fixed indications. On the production side, enormous development has taken place: the production area for our blanks has increased 20-fold compared with the initial set-up and has been continuously upgraded with cutting-edge technology. By now, we are one of the five largest worldwide producers of dental zirconia blanks (Fig. 1).

What, specifically, were the most important innovations in this context?

Noack: Certainly the most important innovation was Ceramill ZI, our first self-developed zirconia blank. With this material, we have achieved the goal of being able to offer the production of maximum widespan restorations in a secured manner—that was a fundamental innovation. The development of Ceramill Zolid was essential too: we were looking for enhanced aesthetics and greater translucency at the time (Fig. 2). To this end, some manufacturers took the approach of increasing the sintering temperatures—which, as we know today, was indeed the simpler approach, but also the riskier one from a materials science point of view. Together with our longstanding development partner and exclusive raw material supplier Tosoh Corp. in Japan, we, in the scope of intense cooperation, successfully developed our first translucent material that does not require an increase of the sintering temperature. Moreover, the aesthetic zirconia materials Zolid FX Multilayer

Fig. 1: The zirconia blanks are produced exclusively in Austria.

and Zolid Gen-X Multilayer, which, by virtue of their translucency and colour gradients, are used monolithically in a wide variety of ways for fixed dentures, also constituted important innovations (Figs. 3 & 4). The last major innovation of the more recent past is surely Zolid DRS, a material that can be sintered in 20 minutes with the aid of the corresponding sintering furnace, Ceramill Therm DRS. Just the shortening of the sintering time from formerly 8 hours to less than one-sixteenth of that, if nothing else, shows the advances that could be achieved through ongoing development.

Prof. Stawarczyk, in the scope of your work as scientific director, you have been involved in the assessment of materials from Amann Girrbach a number of times. Do you remember the beginnings of your expertise on zirconia as well as subsequent developments?
Prof. Stawarczyk: Yes, I remember it well: I assessed the first zirconia discs for Amann Girrbach at a very early stage, and I appreciate how much knowledge and work are involved. I'm all the more glad to see how successful zirconia has become and what standing Amann Girrbach has achieved today. We have examined almost every zirconia modification of Amann Girrbach at our department and have an excellent knowledge of the materials. Our most recent joint project was the development of a high-speed sintering furnace with appropriate zirconia—which has been on the market since last year. This development was implemented in the scope of a cooperation project funded by Zentrales Innovationsprogramm Mittelstand—a federal programme that aims to foster the innovative capacity of small to medium-sized enterprises—based on the knowledge we had jointly gained over many years.

What is your assessment of the future of zirconia in dental applications, and what are the research focuses?
Prof. Stawarczyk: Since its introduction, zirconia has been on the dental market as 3Y-TZP material, then since 2015 as 5Y-TZP and since 2017 as 4Y-TZP. Thus, work on the processing of this material has been ongoing for years. Faster sintering of this material has been achieved while preserving good mechanical properties, thus enabling savings in terms of valuable work time. Through the various modifications, the material has furthermore become more and more enhanced aesthetically. The colouring recipes are continually optimised, and the aesthetic aspect is always compared to that of silicate ceramics. The various modifications are increasingly combined within a blank in order to achieve good aesthetics along with high-quality mechanical properties. At the moment, in my opinion, the focus is on considering the system as a whole, which also includes the CAD/CAM processing and the positioning of the discs in the software. All in all, innovators are seeking to automatise processes more and more and to employ artificial intelligence in this field as well.

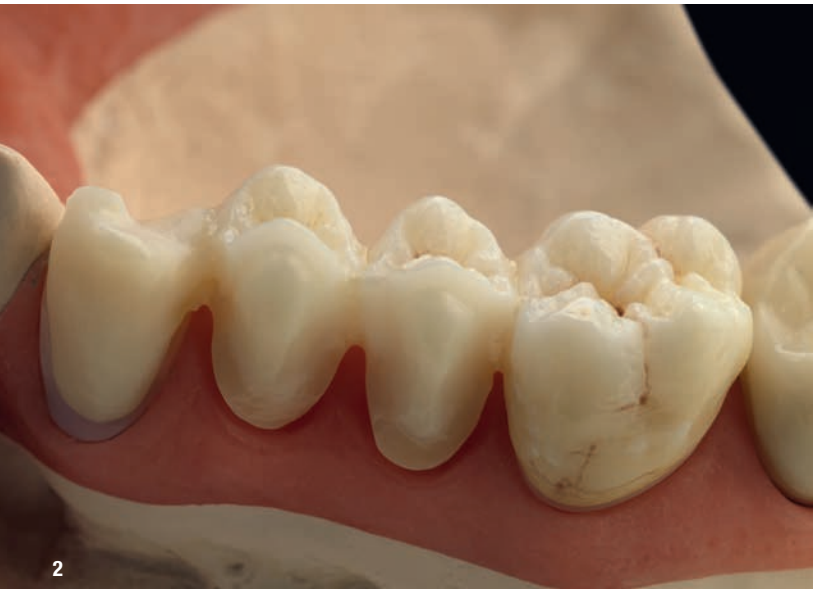

Fig. 2: Bridge from tooth #13 to tooth #16 (infiltrated, reduced frame for tooth #13, vestibular reduction for tooth #14 and 15, monolithic and painted for tooth #16) made by Amann Girrbach from Zolid White, its first Zolid blank, developed in 2012.

Mr Hasegawa, you have been using zirconia from Amann Girrbach since 2011. From the point of view of the user, how have work procedures and methods changed in the course of recent years with the use of zirconia?

Hasegawa: An essential aspect is the switch from analogue to digital. When we started using the Amann Girrbach

"With Amann Girrbach, everything is included [...]— from the material to the CAD/CAM system."

CAD/CAM system several years ago, we were still working a lot with manually produced wax-ups. Today, it is possible without any problems to shape even the fine details digitally; thus, we work entirely digitally. In the field of materials too, much has developed; from opaque to highly translucent properties, a wide range of materials have become available. For fully veneered restorations, we in some cases still use opaque materials such as Ceramill ZI like in the past. In this way, we produce a high brightness value, which gives the restoration a certain natural appearance from inside. We also use these materials to cover discoloured stumps or metallic structures such as abutments. In the anterior tooth area, we use the more translucent and thus more aesthetic materials and normally veneer the frame. In this way, the colour can be better controlled and adapted ideally to the residual dentition. If the entire anterior is renewed, then highly translucent materials such as Zolid FX Multilayer also permit us to perform monolithic fabrication, as in such cases the colouration by the residual dentition plays a less important role. This makes the process considerably faster and more efficient. In the lateral tooth

Fig. 3: Zolid Gen-X is the newest generation of Zolid blanks and an all-rounder, designed for a wide variety of indications.

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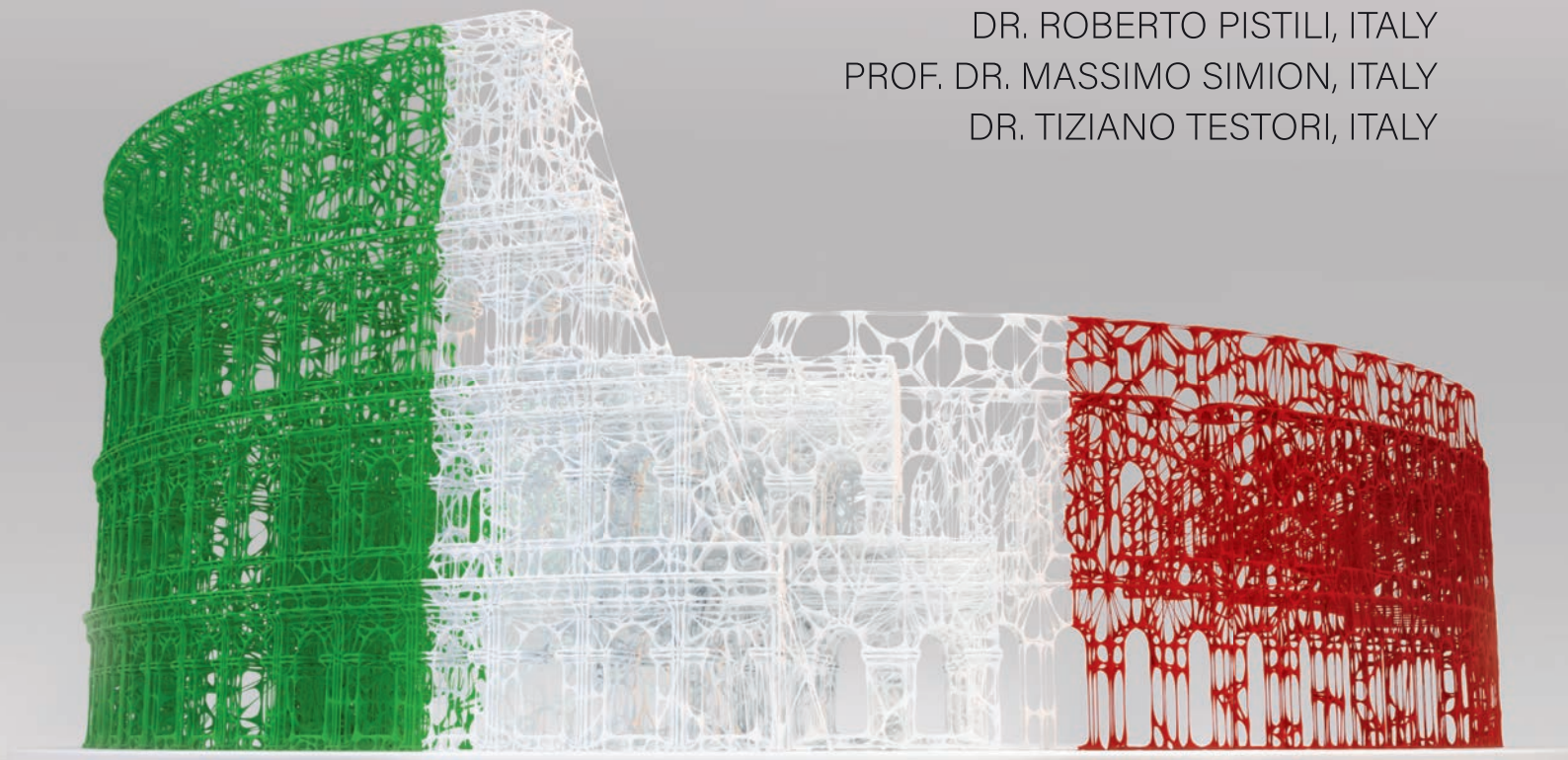

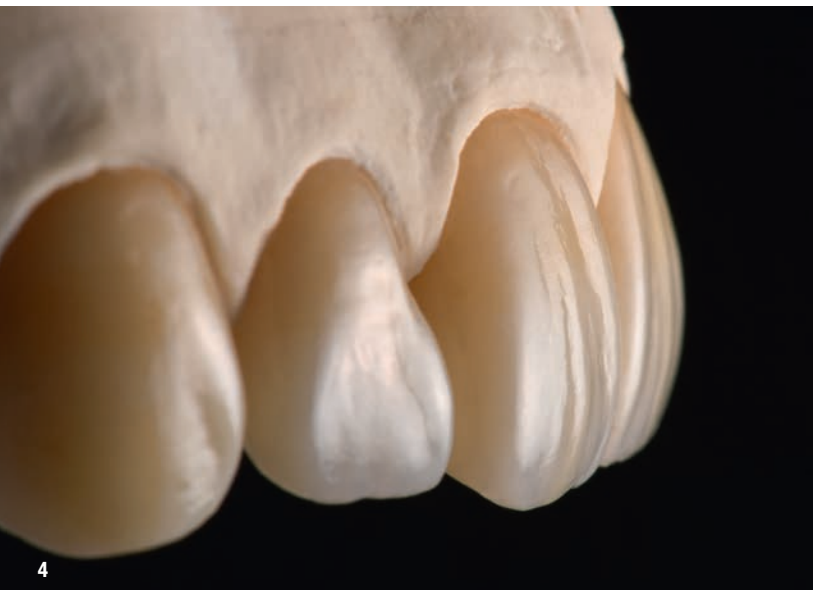

Fig. 4: Crowns for teeth #13–23 (monolithic, painted and glazed) fabricated by certified dental technician Atsushi Hasegawa from Zolid Gen-X—a material for all indications thanks to its excellent properties.

area as well, we work a lot with monolithic restorations. These are considerably less vulnerable to chipping or general material failure.

Why have you opted for materials from Amann Girrbach for more than 11 years now?
Hasegawa: The primary reason is that with Amann Girrbach, everything is included in a consistent system—from the material to the CAD/CAM system. Such a workflow greatly facilitates our work. Another factor which is very important to us is that Amann Girrbach operates in an evidence-based manner. This means that we know that the durability and reliability of the zirconia products have been confirmed in studies by independent testing institutions.

What do you expect in future from industry with regard to zirconia and its processing?
Hasegawa: I think that we can expect developments in the field of 3D printing. Another helpful feature would be shade determination, such as via eLAB or Matisse, prior to the sintering process in order to already know the shade result prior to sintering. This could perhaps in future be effected via coloured fluids.

In conclusion, Mr Noack, where do you, from a manufacturer's point of view, currently see the greatest challenges in connection with zirconia?
Noack: In my opinion, the issues on the application side can be considered resolved from the technical point of view. The challenge currently is to maintain an overview in view of the numerous products offered. Basically, I see a light at the end of the tunnel here though, since those zirconia generations which feature multifunctional usability and will thus in future be predominant are increasingly becoming evident. From a manufacturer's point of view, the constantly increasing statutory and thus documentary obligations and requirements that have to be met are also certainly challenging. However, we perceive these requirements as something very positive, as they contribute to the enhanced safety of the medical device and thus also to greater safety for patients.

about

After working for about eight years in the dental technology field, during which he specialised primarily in fixed and removable prosthodontics and implant prostheses, **Falko Noack** undertook dental technology studies at the Osnabrück University of Applied Sciences in Germany. In the course of his studies, he worked on various projects at the university in the fields of metallography and material testing of dental materials. The topic of his diploma thesis was the development of a process chain for the manufacturing of a pre-sintered zirconia blank. He went on to apply his practical and technological knowledge in research and development at Amann Girrbach, particularly in the field of materials development and CAD/CAM technology.

Prof. Bogna Stawarczyk studied dental technology at the Osnabrück University of Applied Sciences in Germany after completing her dental technician training. Later, she obtained an MSc in dental technology at the University for Continuing Education Krems in Austria, and she completed her doctorate in 2013 at Ludwig-Maximilians-Universität München (LMU Munich) in Germany on the topic of long-term stability of CAD/CAM resins. In 2015, she completed her habilitation in the field of experimental, dental, oral and maxillofacial medicine, with a focus on biomaterials, and was appointed to her current position. She was appointed extraordinary professor at LMU Munich in 2020.

Atsushi Hasegawa acquired his dental technician licence in 1996, and this was followed by a postgraduate course of studies at Kanagawa Dental University in Yokosuka in Japan in 1998. He subsequently worked for 11 years at a dental laboratory in Tokyo in Japan, where he acquired knowledge and skills in the field of occlusion concepts. In 2008, he established his own laboratory in Chigasaki in Japan. Today, he imparts his knowledge in lectures in Japan and worldwide.

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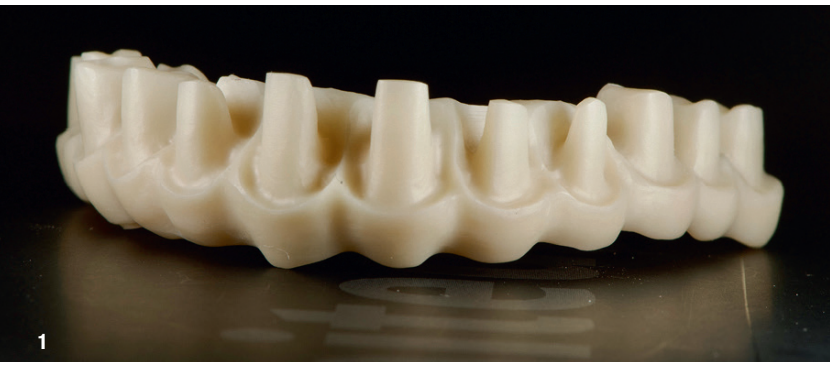

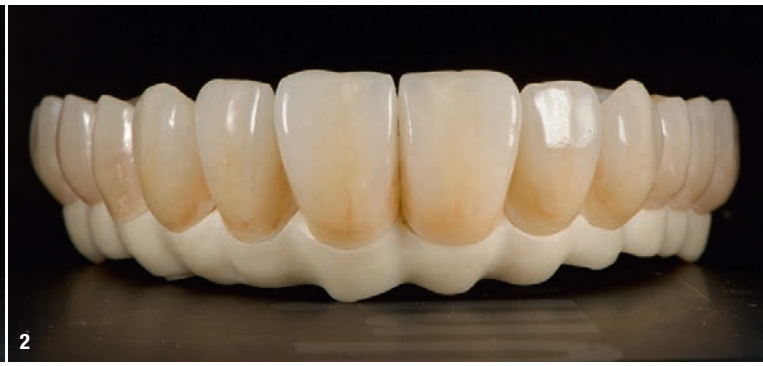

Fig. 1: Sintered bar milled from KATANA Zirconia HTML PLUS. **Fig. 2:** Drawing of chroma map for micro-layering in the anterior region.

Every patient is unique. Patients' specific backgrounds, functional needs and aesthetic demands need to be respected in any prosthodontic treatment plan. However, the importance of an individual treatment approach increases with the number of teeth to be replaced. After all, the impact of the restorations on facial aesthetics and on the patient's quality of life is never greater than when all the teeth are missing. Fortunately, adequate dental materials and techniques are available for a patient-centred, individual approach, no matter what challenges need to be overcome.

A patient with bruxism

In the present case, an elderly male patient with bruxism was in need of a new maxillary denture. Since the placement of five implants in the maxilla, he had had no proprioception in this jaw. This lack of sensation had an impact on the overdenture to be produced: material and design needed to be carefully selected in a way that it would withstand uncontrolled masticatory forces. As technical complications are easier to address than

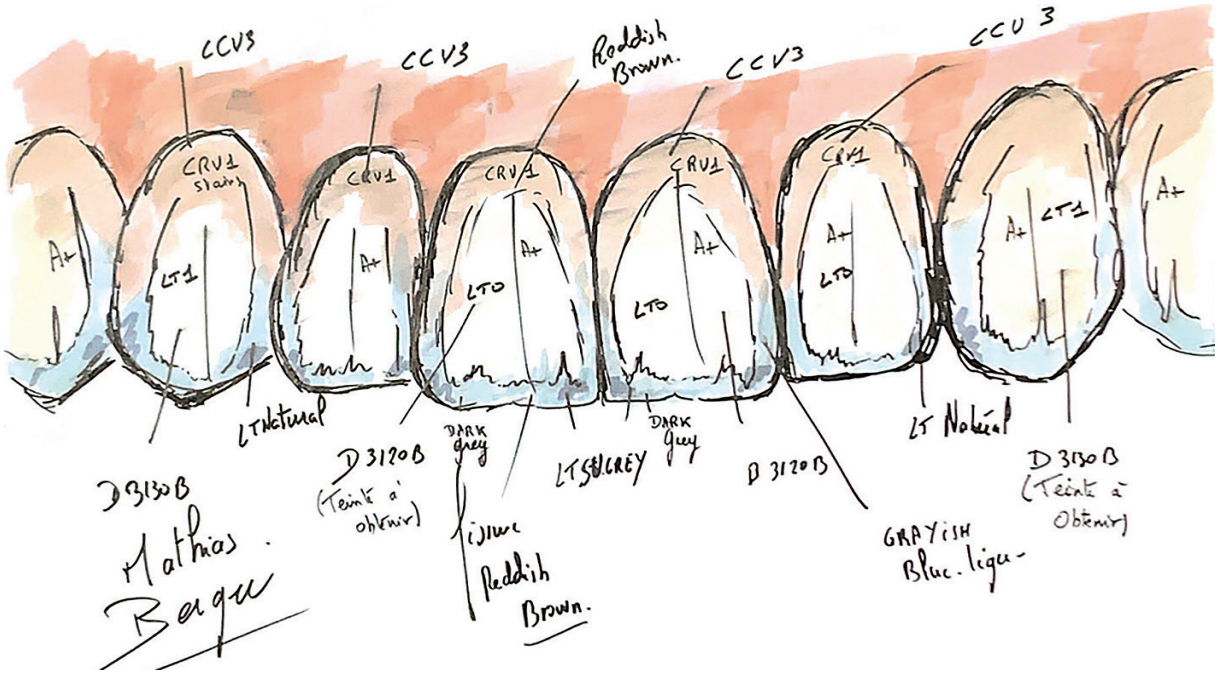

Fig. 3: Finished crowns with individual, age-appropriate shade effects on the sintered bar.

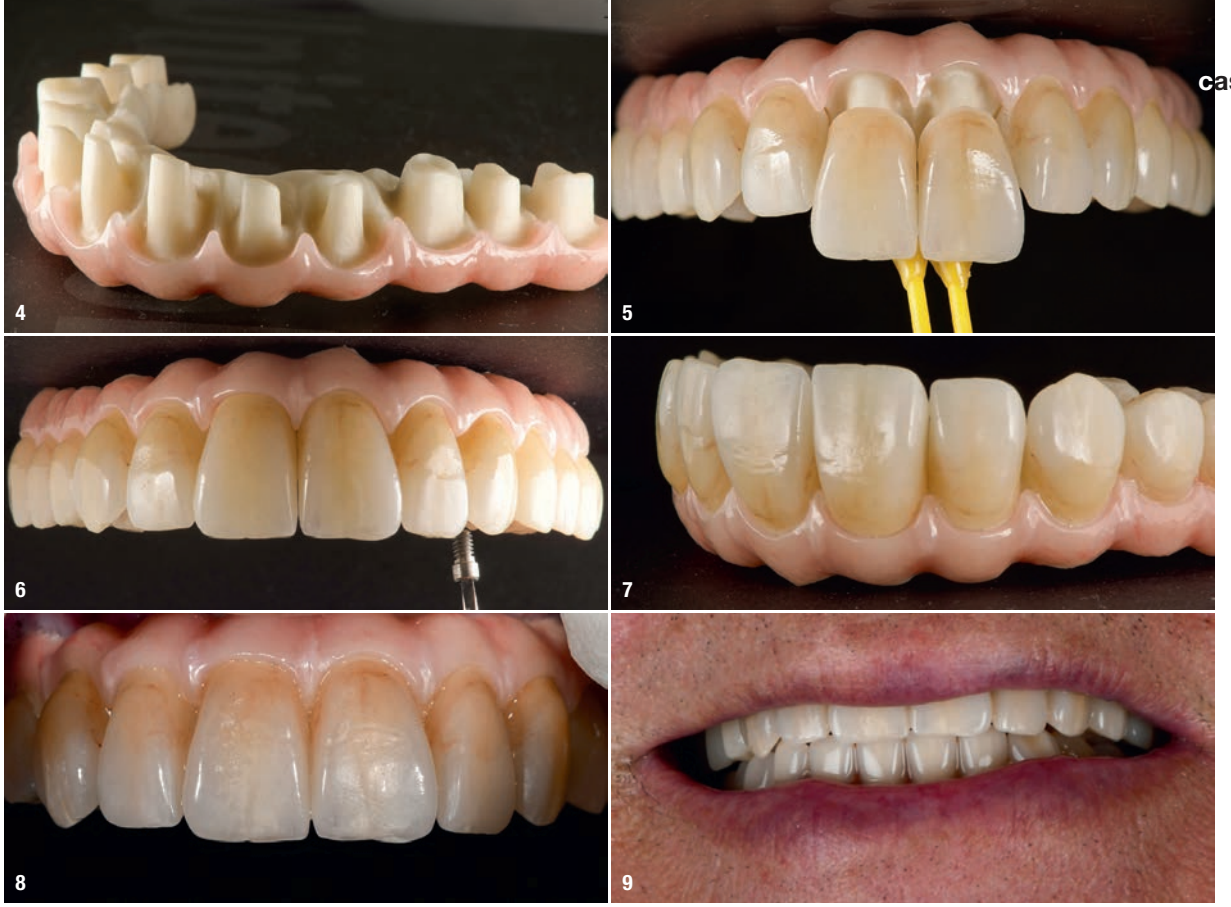

Fig. 4: Bar with individualised gingival areas. **Fig. 5:** Placement of the central incisor crowns on the bar. **Fig. 6:** Occlusal screw access hole in the finished overdenture. **Fig. 7:** Overdenture ready for try-in. **Fig. 8:** Intra-oral try-in of the aesthetic overdenture. **Fig. 9:** Final situation.

biological complications, the overdenture should not be unbreakable; instead, the replacement of single units should be easily manageable.

Two-part denture design

The solution was a two-part design consisting of a milled bar with a gingival area and tooth abutments (Fig. 1) and of single crowns. The material of choice for the bar was KATANA Zirconia HTML PLUS (Kuraray Noritake Dental), which has a uniform flexural strength of 1,150 MPa throughout the disc, and the single crowns were milled from KATANA Zirconia YML, which offers natural translucency and strength gradation. Whereas a monolithic design was selected for the posterior crowns, the six crowns for the anterior region received a micro-cutback for aesthetic micro-layering with CERABIEN ZR porcelain (Kuraray Noritake Dental). Customisation of the anterior crowns (Fig. 2) was performed with the internal stains Cervical 1, Grayish Blue, Dark Grey and A+. The finishing layer on the incisors was created using LT0 materials mainly, as well as some CCV-3 on the cervical area and LT Natural on the mesial and distal lobes. On the canines, LT1 was used instead of LT0. The posterior crowns were merely finished with liquid ceramics (CERABIEN ZR FC Paste Stain, Fig. 3).

After checking of the fit of the crowns, the gingival areas of the bar were individualised using CERABIEN ZR tissue porcelain (Fig. 4). Subsequently, the crowns were luted to the zirconia abutments (Fig. 5), leaving screw access holes in aesthetically uncritical positions (Figs. 6 & 7).

Owing to an excellent fit on the implants (Fig. 8), it was possible to fix the overdenture with the screws immediately, to close the access holes with composite and then to discharge the patient (Fig. 9).

Conclusion

This patient case is a good example of how important it is to respect the patient's background, age and specific demands when producing dental restorations. Thanks to the great variety of restorative materials with different mechanical and optical properties available, it is possible to create suitable prostheses for virtually every patient.

However, for this purpose, it is important to stay up to date regarding new products launched and techniques developed. This way, it is often even possible to create beautiful and durable solutions in a simplified and efficient procedure such as micro-layering on innovative zirconia with a high aesthetic potential.

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Digital implant planning in combination with a conventional prosthodontic workflow

Dr Mats Wernfried Heinrich Böse & Andrea Rosinski, Germany

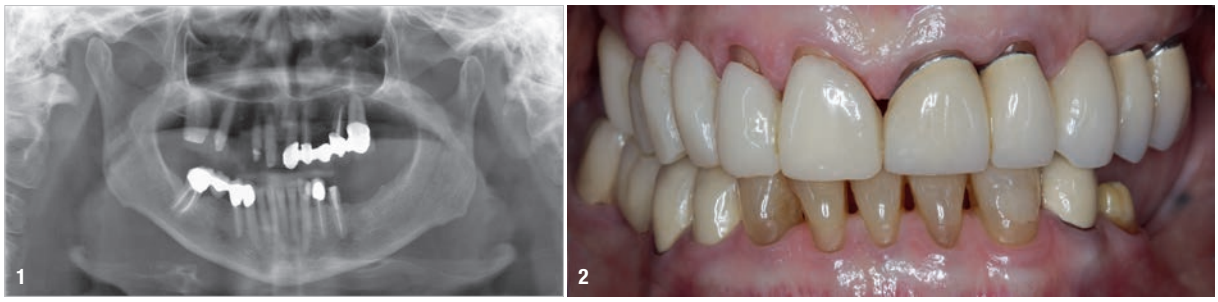
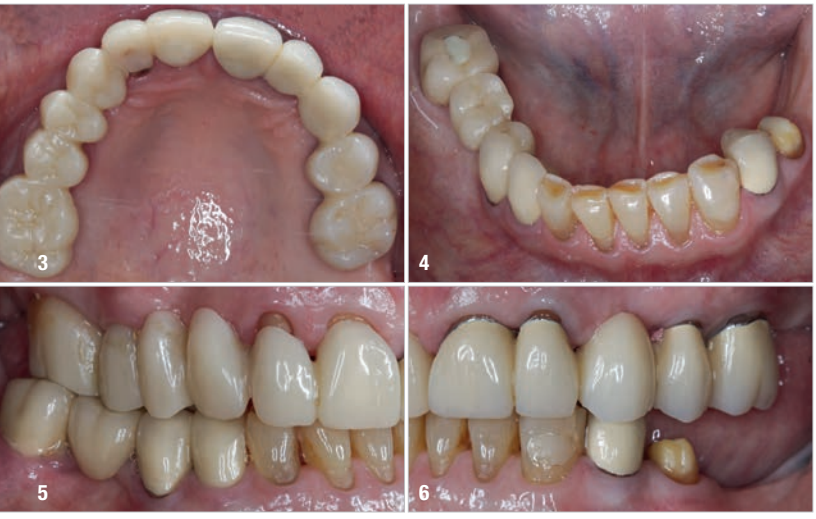


Fig. 1: Panoramic radiograph of the initial situation. **Fig. 2:** Preoperative situation, frontal view.

Introduction

It is expected that the trend towards digitalisation will continue within dentistry.[1] For practising dentists, this may give rise to the question of economic efficiency and the consideration of which aspects of a workflow can be advantageously digitised first. Implementing digitalisation in a specific clinical case should always be analysed according to the question of how digitalisation can improve existing workflows for both the practitioner and the patient. This analysis may also be influenced by the experience of the dentist and his or her team in using specific techniques.



Figs. 3 & 4: Preoperative situation, occlusal views. **Figs. 5 & 6:** Preoperative situation, lateral views.

However, the correct 3D placement of a dental implant is one of the most important prerequisites for long-term treatment success.[2] It can reduce the risk of possible technical and biological complications. Therefore, specific options within digital dentistry for the placement of implants in a prosthetically driven way should be implemented whenever possible. Applying implant planning software is an example of this and can be chosen independently of the following treatment steps.

In my opinion, digitalisation within dentistry is a great tool. However, it does not inevitably simplify everything, but enables more predictable outcomes. It does not always require investments in costly equipment. Sometimes a smart combination of new possibilities and proven techniques add value to an individual case and experience. The following clinical case is intended to illustrate this.

Clinical case

A 72-year-old female patient presented to the Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders at Charité–Universitätsmedizin Berlin. The pretreating dentist had referred her with a view to the expected complexity of the case. She required extensive prosthetic rehabilitation (Figs. 1–6) and had discomfort in her left temporomandibular joint. Her expectations of the treatment result were high, and she wanted to be restored with single crowns and fixed dental prostheses only.

After three months of therapy with an adjusted splint in the lower jaw to adjust the occlusal height and centric condylar position, prosthetic rehabilitation was planned.

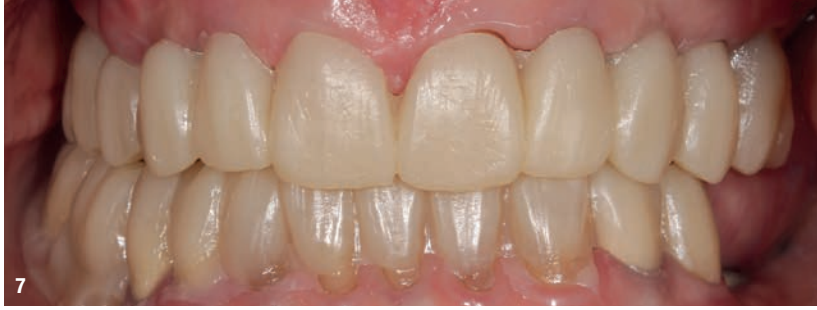


Fig. 7: Conventional mock-up after conventional wax-up using transfer splints and provisional material (Luxatemp Star, DMG).

Owing to the temporomandibular joint discomfort and compromised residual teeth, care was taken to plan an adequate number and position of dental implants. During the discussion with the master dental technician (MDT), Andrea Rosinski of Dental-Concept Berlin, it was decided to place one implant in region #13, one implant in region #23 and one implant in region #36 to achieve satisfactory function and aesthetics. Consequently, the prosthetic treatment goal was defined with a conventional wax-up and mock-up (Fig. 7). The mock-up helped to manage the patient's expectations regarding her new smile in close consultation with the MDT.

A digital wax-up and mock-up would have been an option; however, a conventional way of working without additional digital equipment was chosen to elaborate the possibilities of combining new and established techniques. Furthermore, the MDT is highly specialised in this type of workflow and the equipment required for a digital wax-up and mock-up was not

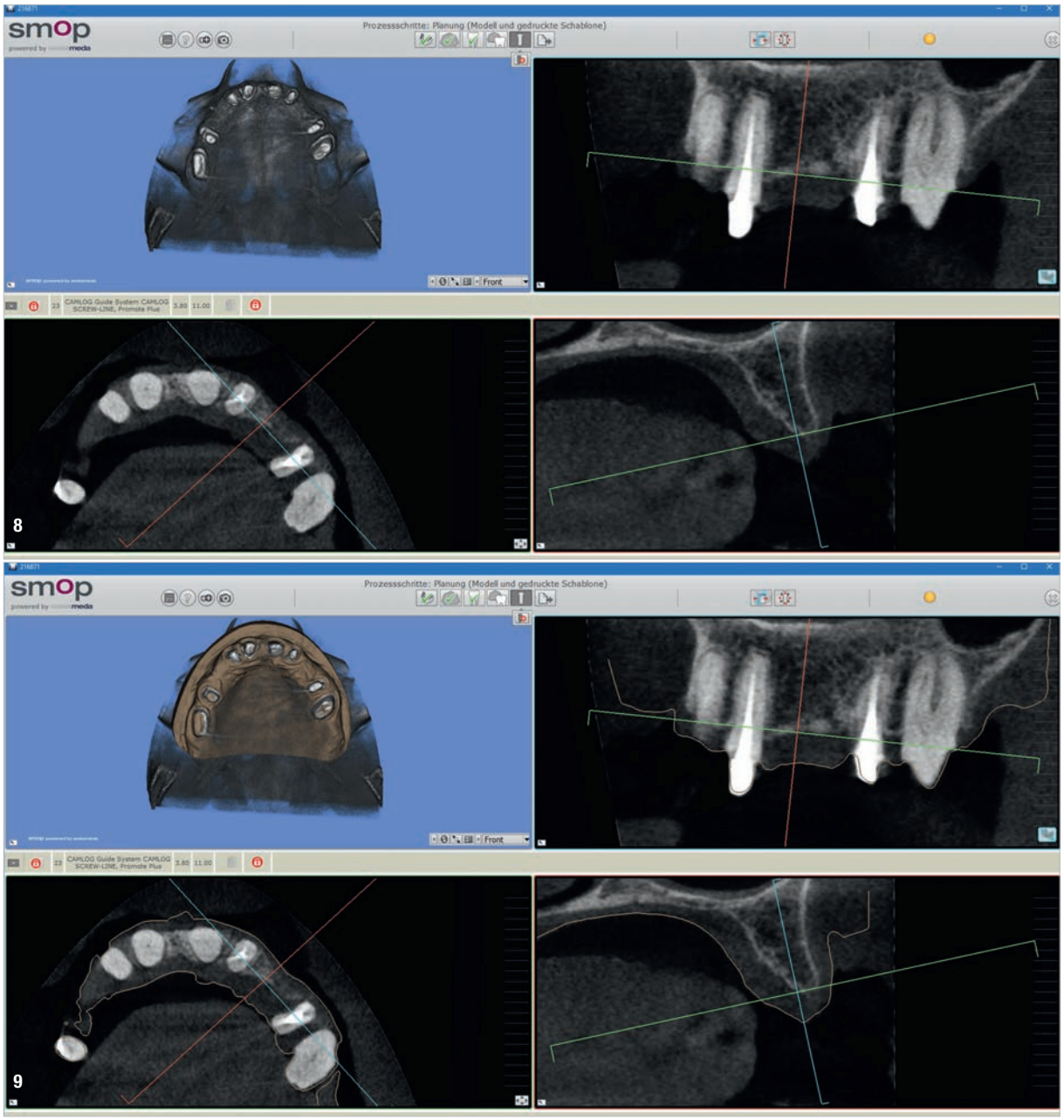
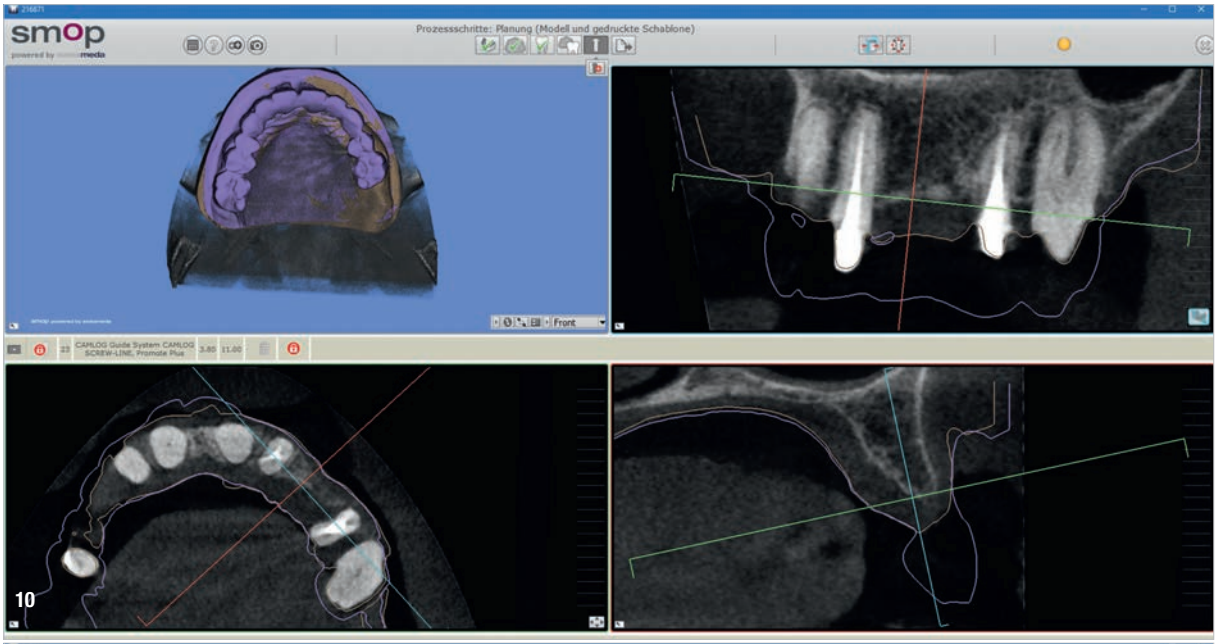


Fig. 8: Digital planning of the implant position in region #23 based on the CBCT scan. **Fig. 9:** CBCT scan matched with the STL data set of the maxillary situation model (displayed in brown). Matching was done by selecting three corresponding points on the CBCT scan and model data sets. Like in this case, fine adjustments by the implantologist are sometimes necessary.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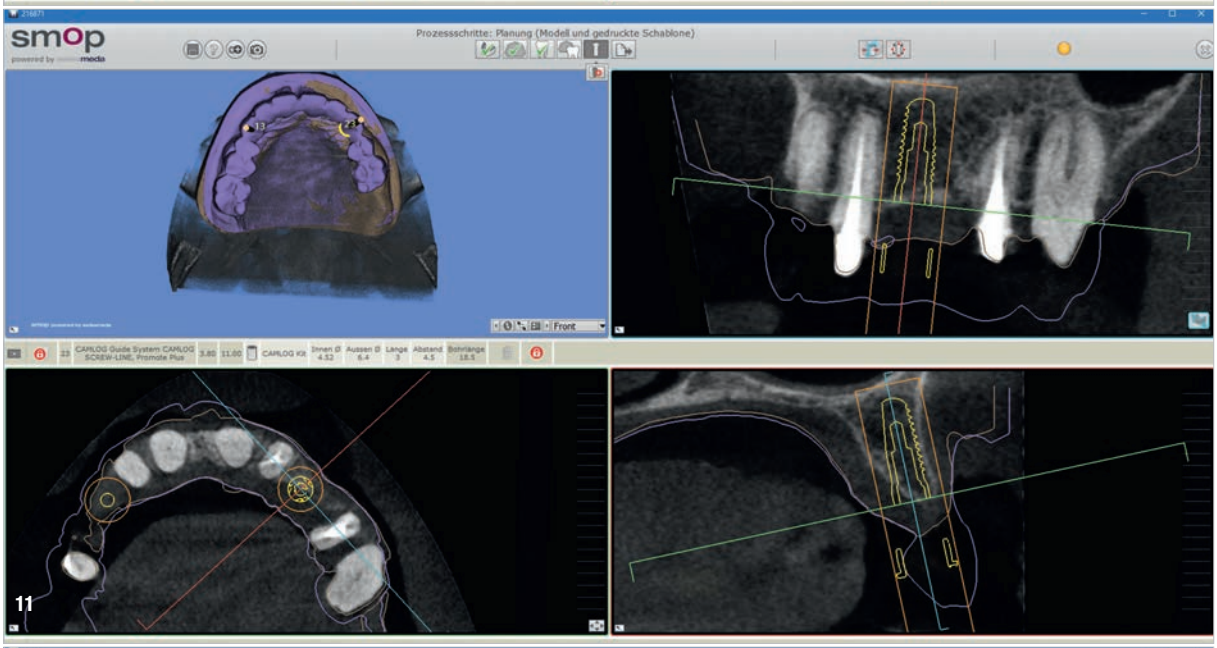
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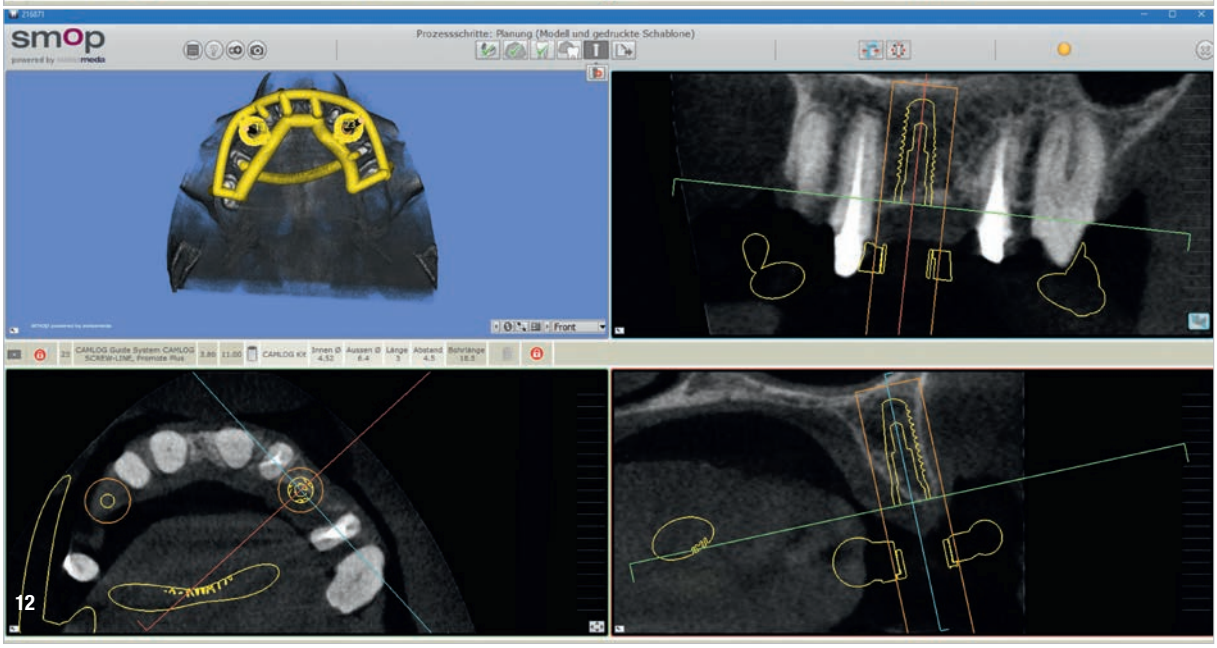
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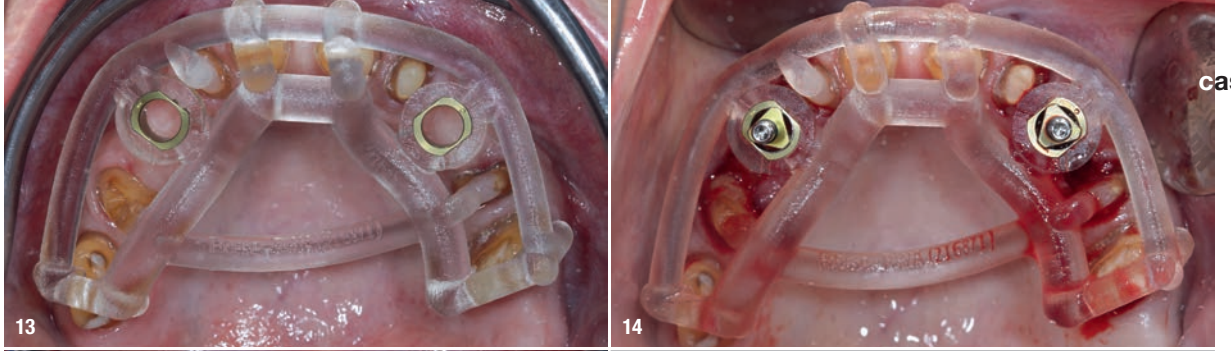


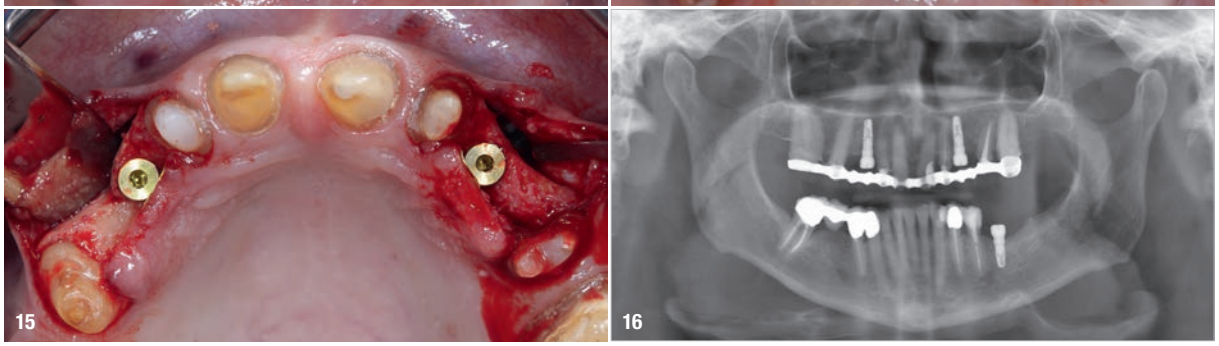
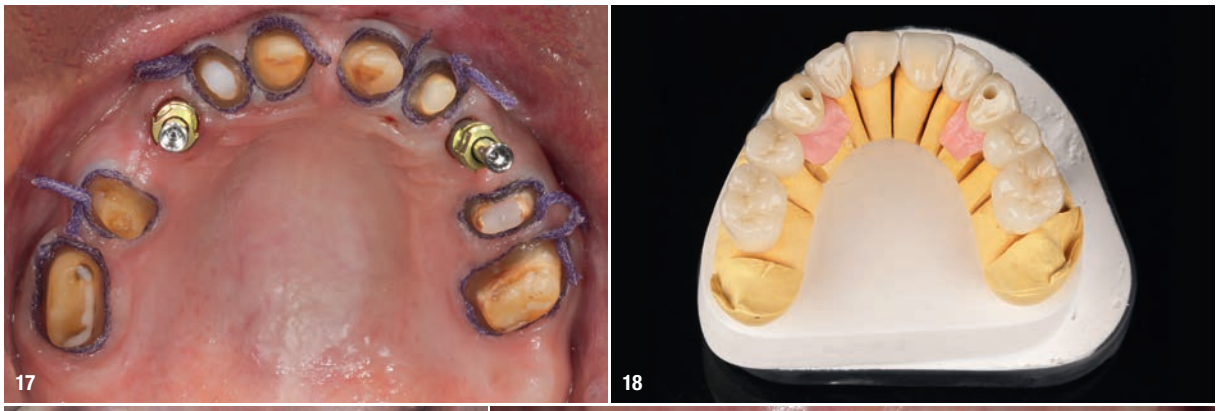


Fig. 10: CBCT scan with additionally matched STL data set of the maxillary wax-up (displayed in purple). Scanning the mock-up after minor adaptations would also have been possible. **Fig. 11:** Alignment in region #23, respecting the imported wax-up data set. A 3.8 × 11.0 mm CAMLOG SCREW-LINE Promote plus implant (CAMLOG) was chosen. Occlusal screw retention was aimed for. The implant and drill sleeve are shown in yellow and the safety cylinder in orange. **Fig. 12:** Pre-op construction of the drilling guide for fully guided implant placement in regions #13 and 23. The drilling guide is shown in yellow. **Fig. 13:** Pre-op try-in of the drilling guide. Colour-coded drill sleeves indicate the diameter of the implant to be placed. **Fig. 14:** Intra-op occlusal view after fully guided implant placement. The occlusal stops of the screw-mounted insertion posts define the final implant position. Trying to insert the implant deeper than planned leads to loss of primary stability and thus should be avoided. **Fig. 15:** Intra-op occlusal view after removal of the insertion posts and insertion of the respective cover screws. **Fig. 16:** Panoramic radiograph of the situation with the healing abutments in place.

available. This may also represent a problem among practitioners broadly regarding implementation of digital workflows.

Therefore, the first step was digitalisation of the situation model and prosthetic treatment goal. Matching with the CBCT data set was performed in the planning software SMOP (Swissmeda; Figs. 8–10). This ensured ideal alignment of the implants regarding function and aesthetics (Fig. 11).

Subsequently, a drilling guide was designed and delivered by the manufacturer (Fig. 12). Guide sleeves for a fully guided implant placement protocol were inserted.



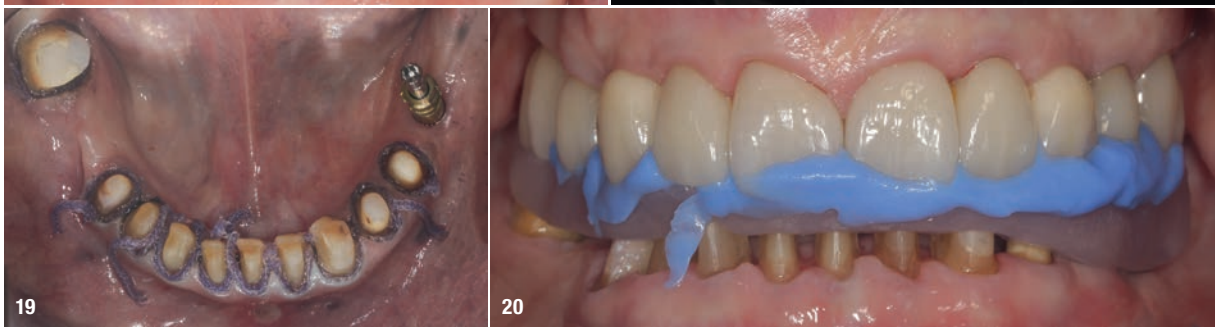
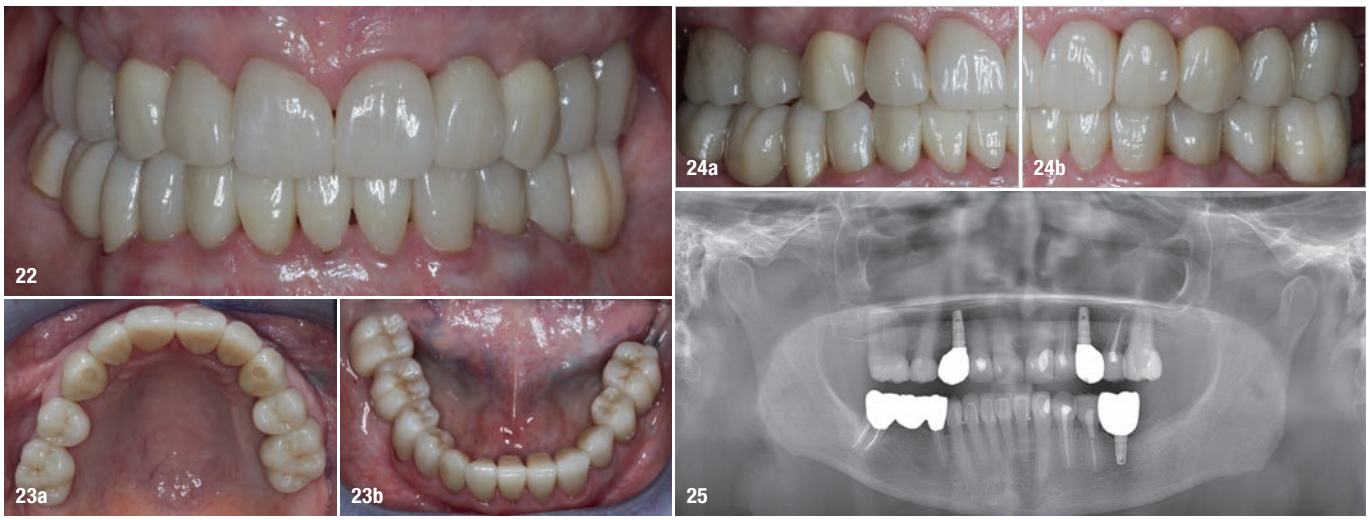


Fig. 17: Intra-oral occlusal view of the upper jaw before impression taking. The impression was taken with an individual tray using the double-thread technique and polyether materials. **Fig. 18:** Definitive maxillary restorations by Andrea Rosinski. **Fig. 19:** Intra-oral occlusal view of the lower jaw before impression taking with an individual tray using the double-thread technique and polyether materials. **Fig. 20:** Bite registration of the lower jaw with the aid of a back bite registration plate attached to the previously restored upper jaw. After fine adjustments, registration was carried out with a registration material (LuxaBite, DMG).

Fig. 21: Definitive mandibular restorations of lithium disilicate and multilayer zirconia by Andrea Rosinski.

After preoperative try-in of the guide (Fig. 13), the implants (CAMLOG) were placed as planned (Fig. 14). The drilling guide and screw-mounted insertion posts were removed, and the implants were left to heal for three months (Fig. 15). After uncovering, the implants were supplied with prefabricated healing abutments for an additional two weeks for soft-tissue management. A panoramic radiograph of the situation with the healing abutments in place was taken (Fig. 16).

A combination of digital—in this case utilisation of implant planning software—and conventional techniques can lead to highly satisfactory results. The restoration of the edentulous sites of regions #13 and 23 demanded a detailed consultation with the MDT. A conventionally manufactured wax-up and mock-up were helpful to integrate the patient's expectations and the functional and aesthetic demands when planning the treatment. Malpositioning of dental implants (especially in regions #13 and 23) could have led to compromised prosthodontic results, additionally risking long-term results. This was avoided by consequent utilisation of backward planning. Apart from the SMOP fee for planning and manufacturing of the guide, there was no need for any investments in additional digital technology for treatment implementation or equipment for performing part of the treatment steps digitally. Therefore, this workflow is easy to implement for any practitioner and has little additional cost for the patient, resulting in a predictable outcome.



Figs. 22–24b: Different views of all the restorations in place. **Fig. 25:** Final radiograph. Remnants of the cementing adhesive were removed after the radiograph was taken.

After the additional healing period, impressions were taken with an open-tray technique and polyether impression materials (Impregum and Permadyne, 3M ESPE; Fig. 17). After definitive restoration of the idealised maxilla with lithium disilicate (IPS e.max, Ivoclar) and multilayer zirconia (Eos, Orodent; Fig. 18), the lower jaw impression was taken (Fig. 19). Bite registration was performed step by step and subsequently checked with a bite registration plate (Fig. 20). The definitive mandibular prosthetic restorations were manufactured from lithium disilicate and multilayer zirconia and seated and a final panoramic radiograph taken (Figs. 21–25).

Conclusion

This case demonstrates that predictable functional and aesthetic restoration with implant-retained prostheses is possible even without costly investments in digital equipment.

Editorial note: A list of references is available from the publisher.

about

Dr Mats Wernfried Heinrich Böse completed his dentistry degree at the University of Münster in Germany. In 2021, he completed the European Association of Dental Implantologists' (Bundesverband der implantologisch tätigen Zahnärzte in Europa) specialty training in implantology and received his doctoral degree on the topic of root analogue implants from Charité–Universitätsmedizin Berlin in Germany. He previously worked in private practice in Essen in Germany and in Berlin and has been a dentist and research assistant at Charité in the Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders since 2019.

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Implant replacement of congenitally missing incisors using a surgical guide fabricated in-office

Drs Sean Meitner & Gregori M. Kurtzman, USA

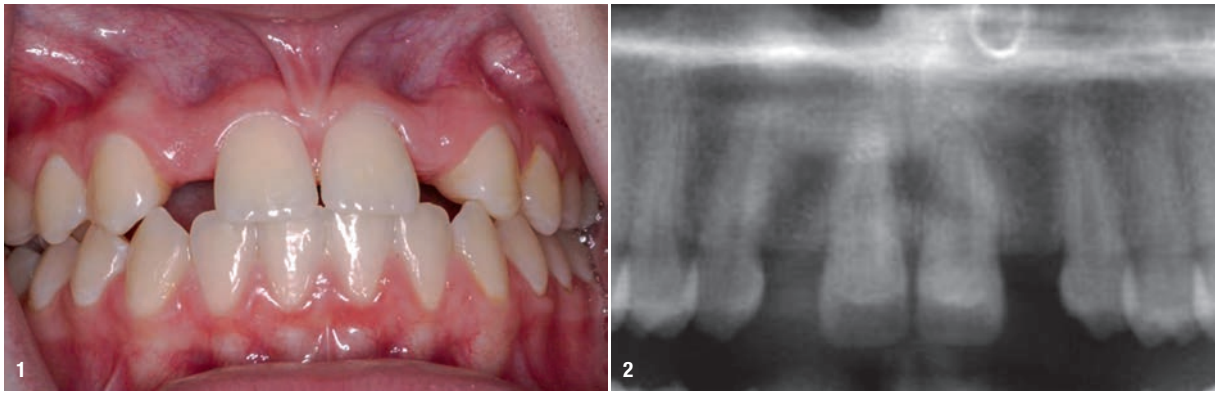
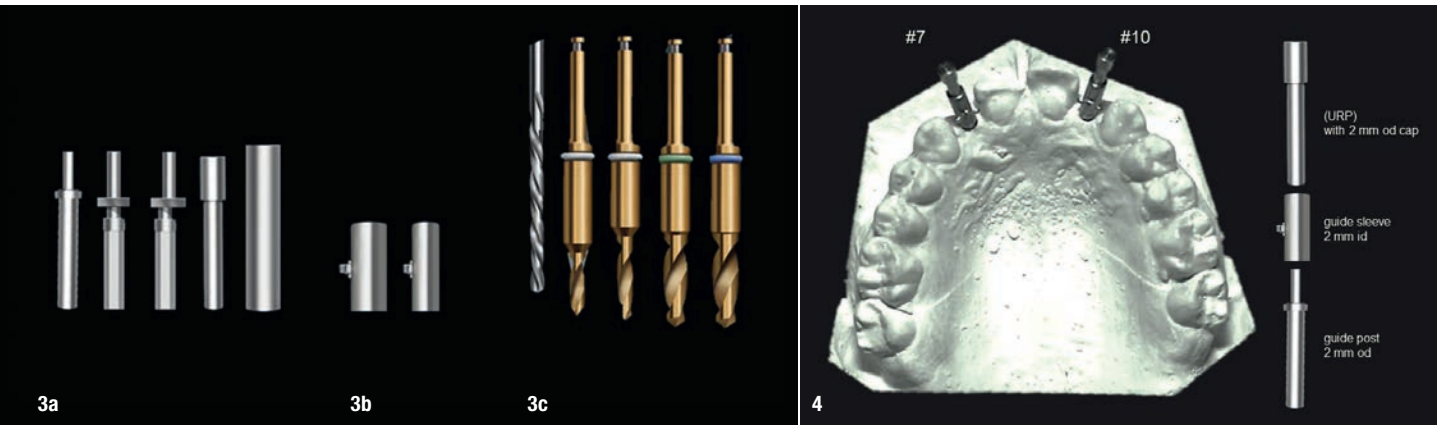


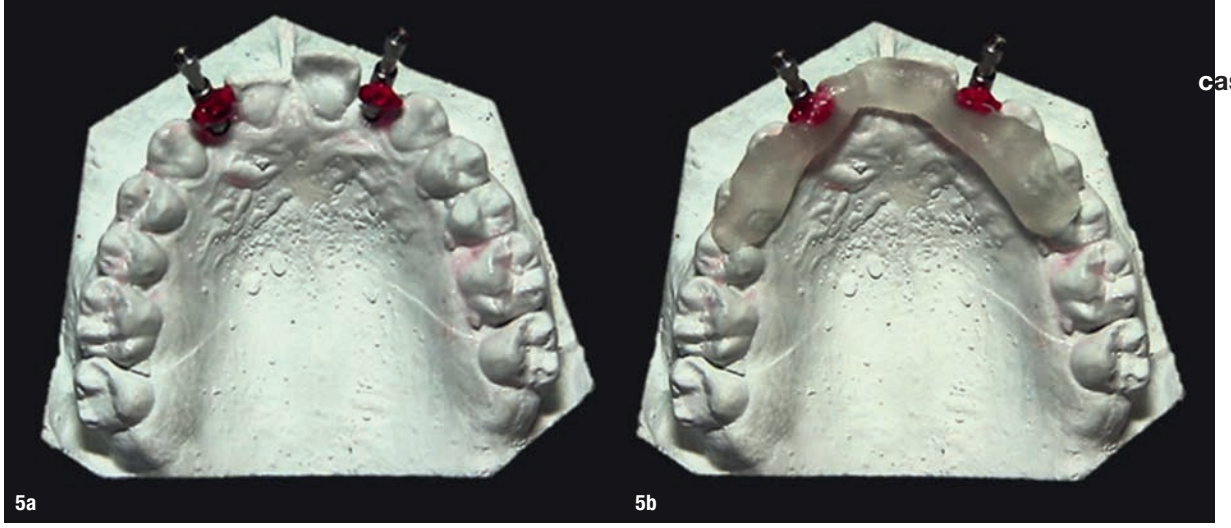
Fig. 1: Bilateral congenitally missing maxillary lateral incisors with associated facial osseous defect on the ridge. **Fig. 2:** Radiograph of the maxillary anterior demonstrating the root positions adjacent to the edentulous spaces at the missing lateral incisors.

Introduction

Replacement of congenitally missing lateral incisors can pose challenges that can lead to clinical complications.[1] These are related to several factors, including angulation of the premaxilla (triangle of bone)[2] and depression of the facial plate due to lack of development related to the missing permanent tooth. Traditional radiographs lack the information necessary to understand the anatomy in the facial–palatal dimension, and this can lead to dehiscence of the facial aspect of the implant when placed freehand using a flapless technique. A flap can be elevated prior to osteotomy preparation so that visualisation of the osseous anatomy can be achieved, allowing the osteotomy to be angled to prevent dehiscence. Clinically, freehand, non-guided site preparation has the risk that the practitioner may overcompensate for the facial defect and angle of the premaxilla, creating an osteotomy that



Figs. 3a–c: Components of the Guide Right system. Guide posts **(a)**. Guide sleeves **(b)**. The 3.85 mm tapered depth stop drills **(c)**. **Fig. 4:** Guide posts inserted into the pilot holes created in the edentulous sites on the cast and 2 mm id x 2.4 mm od x 8 mm L thin-walled guide sleeves placed over the posts, the cleat positioned on the palatal side. URP = upper removable part.



Figs. 5a & b: Light-polymerised resin placed over the cleats **(a)** and additional resin placed over the adjacent teeth **(b)** to create the diagnostic guide to be utilised during the CBCT scan.

is angled too far to the facial aspect, creating restorative challenges in the aesthetic zone.

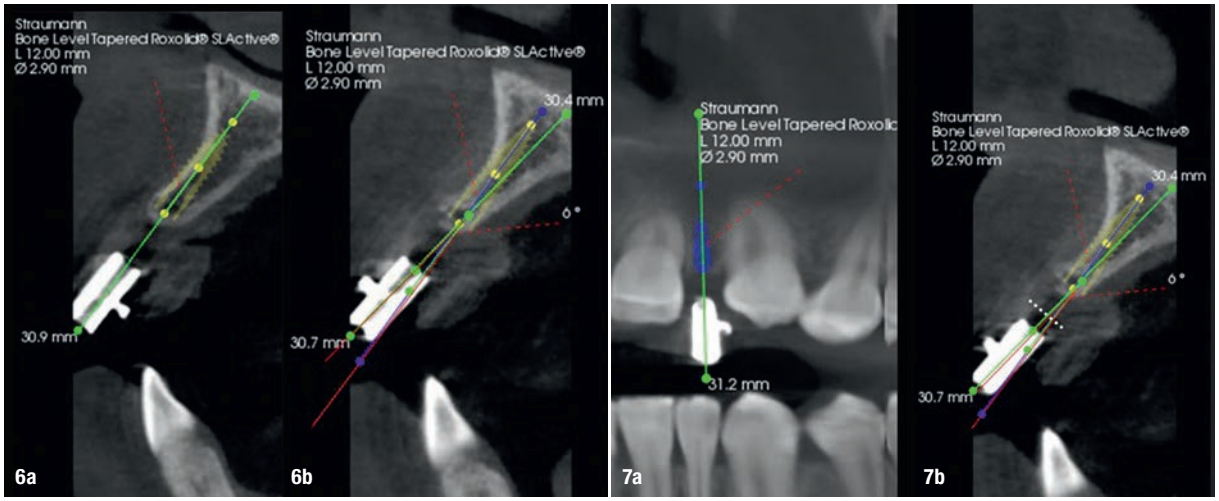
3D evaluation by CBCT provides greater information on the dimensions of the edentulous site to allow implant planning and utilisation of a flapless technique while ensuring that the osteotomy does not create a dehiscence and the implant when placed is surrounded by bone. A guided approach to osteotomy preparation allows a flapless approach for implant placement, making healing for the patient easier and less traumatic. Additionally, an osteotomy is planned that is ideal for the site's osseous anatomy, simplifying the restorative aspect of treatment and yielding a natural aesthetic end result of replacing the congenitally missing incisor.

The article will discuss a case wherein replacement of bilateral congenitally missing lateral incisors was planned utilising a diagnostic guide for a CBCT scan, virtual planning of the implants and correction of the guide for a surgical guide fabricated in-office. The accuracy of this technique has previously been described regarding the accuracy of the geometric approach to guided surgery in an *in vitro* model.[3]

Case

A 17-year-old female patient presented for consultation on replacement of the bilateral missing maxillary lateral incisors with implants (Fig. 1). The patient had undergone orthodontic treatment and the roots of the canines and central incisors bilaterally were parallel, providing spacing for possible implant placement. Examination noted that a facial defect on the ridge was present at both lateral sites related to the lack of development of permanent lateral incisors and loss of the primary lateral incisors prior to orthodontic treatment. Evaluation of the preliminary radiographs confirmed adequate space between the roots of the canine and central incisor to accommodate a narrow-diameter implant while maintaining the recommended distance between the natural root and implant on the mesial and distal sides (Fig. 2).

Components of the Guide Right system (DePlaque) would be utilised to create the diagnostic guide to be used for the CBCT scan and the subsequently corrected surgical guide that would be utilised for osteotomy creation (Figs. 3a–c). Preliminary impressions were taken and casts fabricated.



Figs. 6a & b: The right lateral incisor site viewed in cross section in the planning software **(a)**. An angle correction of 6° measured in the software was made to the planned implant positioning based on the anatomy **(b)**. **Figs. 7a & b:** The left lateral incisor site in the tangential view showing that no linear correction was needed **(a)**. Cross-sectional view showing that an angular correction of 6° to the palatal would be required **(b)**.

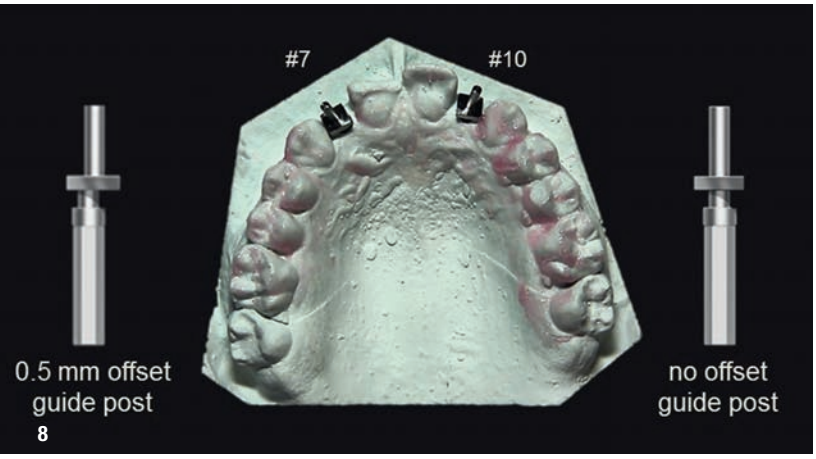


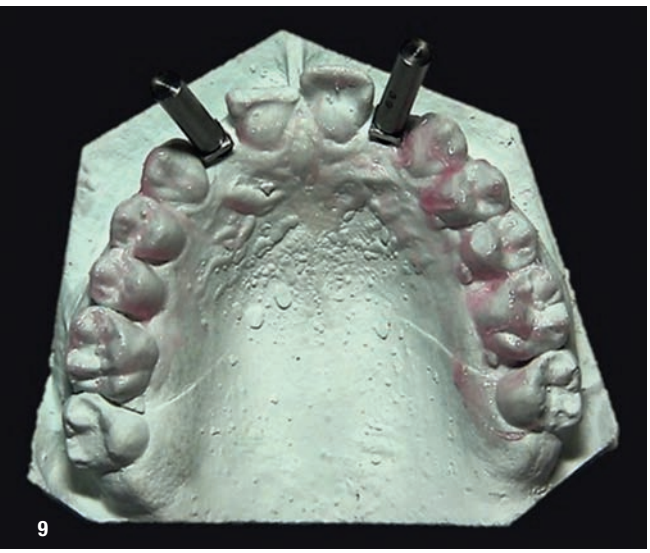
Fig. 8: An offset guide post (0.5 mm) placed into the right site and a straight (no offset) guide post placed into the left site on the cast.

A hole was made in the cast at the planned implant sites with a 2.38 mm drill in a laboratory handpiece, placing each in the ideal prosthetic position centred in the edentulous site at the estimated position and trajectory based on the orientation to the tooth mesial and distal to the missing tooth. A diagnostic guide post was inserted into the hole in the cast, and a 2 mm guide sleeve was placed over the post with its retention element (cleat) oriented to the palatal aspect (Fig. 4). A two-piece guide post upper removable part (URP) with cap was positioned over the 2 mm guide post and then a 2 mm guide sleeve was placed on the URP. This narrower 2 mm guide sleeve provided more accuracy for the radiographic diagnosis. The palatal and occlusal surfaces of the cast were lubricated to prevent resin adherence when the guide was fabricated. A light-polymerised resin (primopattern LC gel, primotec) was expressed on the cast over the cleat (Fig. 5a), and primosplint resin (primotec) was placed on the adjacent teeth to create a stabiliser for the diagnostic guide when inserted intra-orally, and these were light-polymerised (Fig. 5b). The guide posts were removed from the sleeves, completing the diagnostic guide. The diagnostic guide was inserted intra-orally, and a CBCT scan was taken to evaluate the ideal placement of the implant platform in relation to the osseous anatomy.

The patient returned for a CBCT scan with the diagnostic guide. The guide was inserted intra-orally and the CBCT taken. The scan was imported into the implant planning software (Carestream). The metal sleeve is visible on the scan and its radiolucent centre length allows a trajectory to demonstrate the facial–palatal orientation of the implant if the long axis or position of the original sleeve has been used to guide the implant drills in creating the osteotomy. CBCT tangential and cross-sectional views at both sites were evaluated in the planning software.

The right lateral incisor site, based on the site dimensions, would accommodate a tapered bone-level implant (3.3 mm × 12.0 mm, Roxolid, SLActive; Straumann). It was noted that an offset of 0.5 mm and an angle correction of 6° to the palatal aspect would be necessary (Figs. 6a & b). Additionally, owing to the facial–palatal width of the ridge at mid-height crestally and apically, ridge augmentation would be required to eliminate a dehiscence at the time of surgical placement of the implant.

Evaluation of the left lateral incisor site also determined that an implant of the same type and specifications would be accommodated by the site. The tangential view determined that no linear correction was needed (Fig. 7a), but in the cross section, it was determined that an angular correction of 6° to the palatal aspect would be required



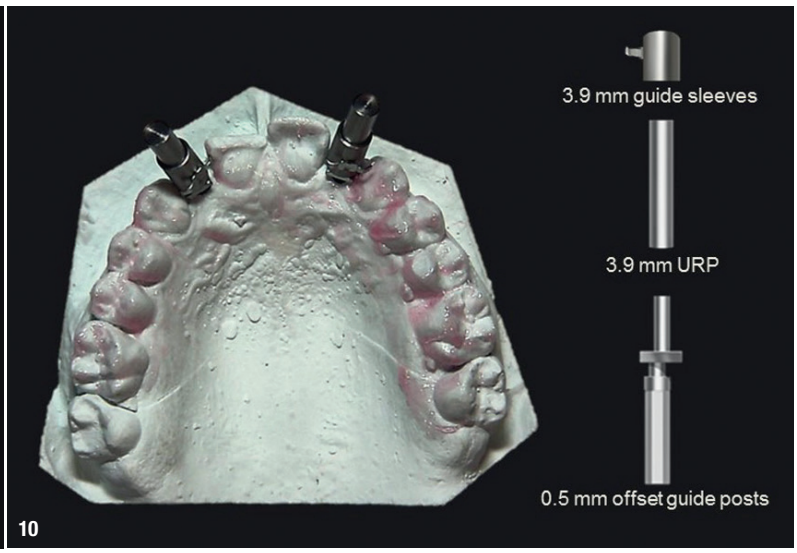
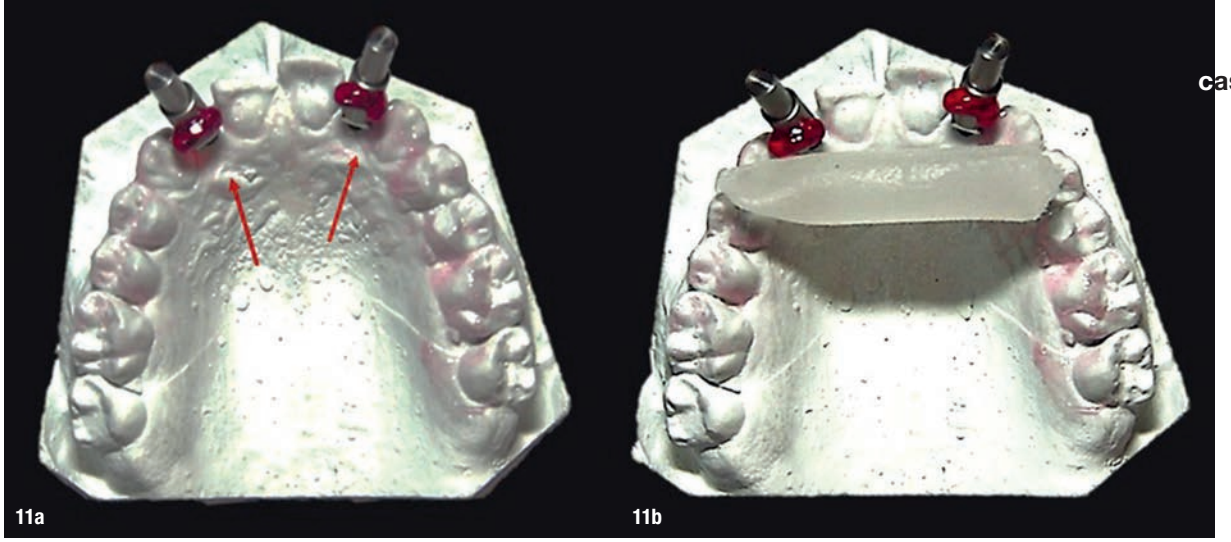


Fig. 9: The upper removable part inserted on to the guide posts at each site and the cast coated with metatouch lubricant to prevent resin sticking to the cast during fabrication of the surgical guide. **Fig. 10:** A 3.9 mm guide sleeve inserted over the upper removable part (URP), the cleat facing palatally.

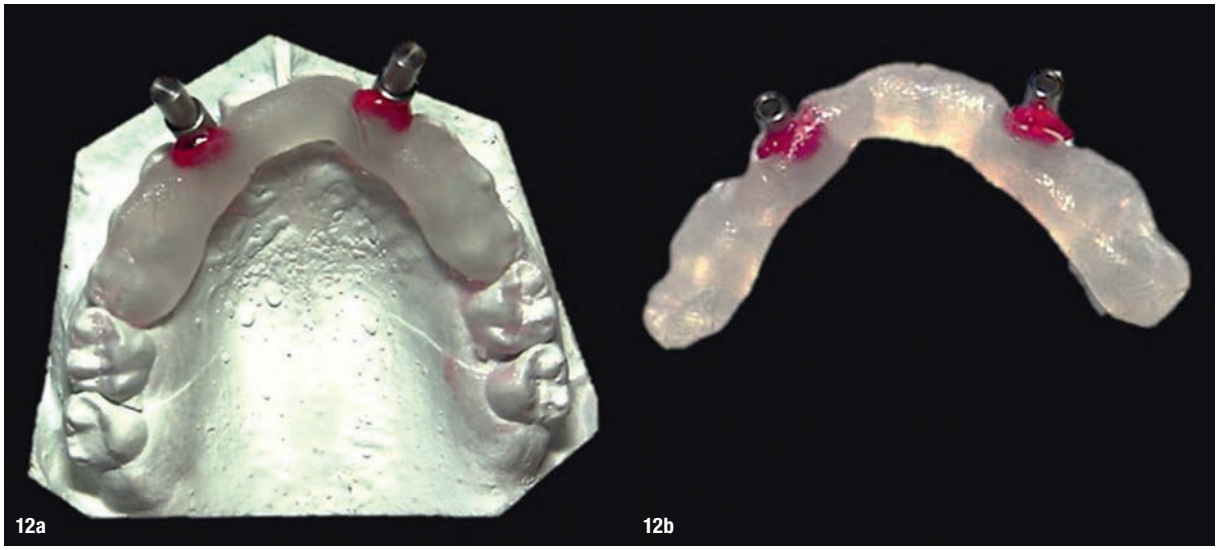


Figs. 11a & b: The cleat on both guide sleeves covered in primopattern gel **(a)** and primotec splint resin adapted to the palatal side of the cast **(b)**.

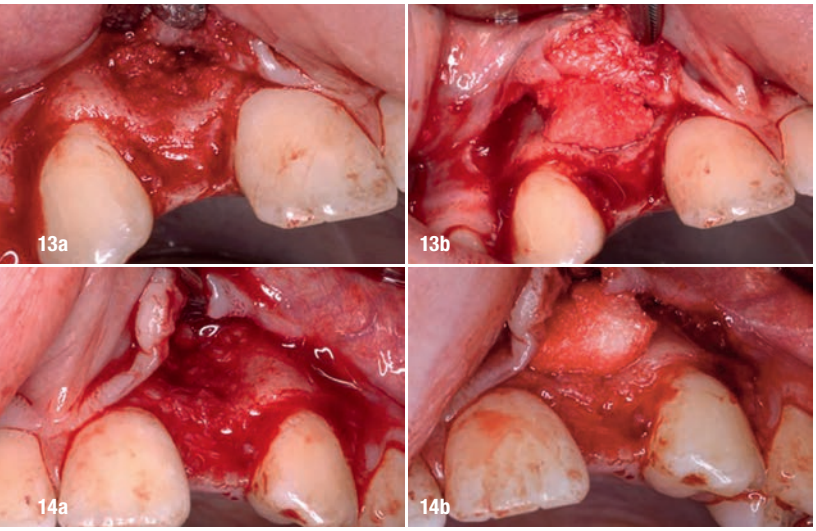
(Fig. 7b). No offset would be necessary on the left site. Like with the bilateral site, because of the facial–palatal width of the ridge at mid-height crestally and apically, ridge augmentation would be required at or prior to the time of surgical placement of the implant.

On the cast, an offset guide post (0.5 mm) was placed into the right site and a straight (no offset) guide post placed into the left site (Fig. 8). A URP was placed over both guide posts, and the cast was coated with meta-touch (primotec) to prevent the resin that would be added for fabrication of the surgical guide from adhering to the cast (Fig. 9). A 3.9 mm guide sleeve was placed over both URPs, the cleat positioned to the palatal side of the cast (Fig. 10). Like with fabrication of the diagnostic guide, primopattern gel was placed over the cleat on each guide sleeve (Fig. 11a) and then a 2.5 cm length of primotec splint resin was applied to the palatal side of the cast (Fig. 11b). The splint resin was adapted to the cleats and palatal and occlusal/incisal aspects of the adjacent teeth on the cast to create the surgical guide and then light-polymerised (Fig. 12a). Coverage of the occlusal/incisal aspect of the adjacent teeth with slight extension on to the buccal aspect of the teeth creates a guide that will be stable intra-orally during osteotomy preparation. The URPs were removed from the cast, allowing removal of the surgical guide from the cast (Fig. 12b).

The patient presented for the surgical appointment, and the consent forms were reviewed and signed by the patient's parent. Local anaesthetic was administered to the sites in the buccal vestibule and palatally. A #15 scalpel blade was utilised to make an incision from the mid-facial aspect of the right central incisor in the sulcus and continued to the mesial aspect of the distal papilla of the canine, and a full-thickness flap was elevated to expose the facial aspect of the ridge at the right lateral incisor site (Fig. 13a). The cortical plate was perforated at multiple points at the facial ridge defect with a surgical bur. An OsteoGen Block (Impladent) was hydrated with the INFUSE XX SMALL KIT (Medtronic), hydrated with 0.7 ml sterile water, divided into halves and placed over each defect on the facial aspect of the ridge (Fig. 13b). OsteoGen is a bioactive, resorbable non-ceramic calcium apatite crystal that is similar to human bone and is



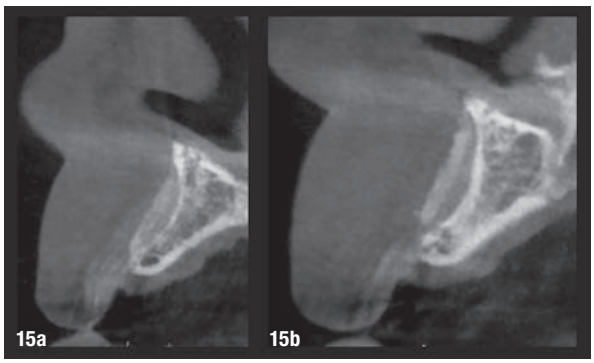
Figs. 12a & b: The primotec splint resin adapted to the adjacent teeth, covering their occlusal/incisal surfaces to aid in stabilising the surgical guide when inserted intra-orally **(a)**. The light-polymerised surgical guide **(b)**.



Figs. 13a & b: The defect at the right lateral incisor site exposed by elevating a flap in the area and bleeding points **(a)**. An osseous graft placed to fill the defect to be even with the adjacent ridge contours **(b)**. **Figs. 14a & b:** The defect at the left lateral incisor site exposed by elevating a flap in the area and bleeding points **(a)**. An osseous graft placed to fill the defect to be even with the adjacent ridge contours **(b)**.

carried by a bovine collagen created from the Achilles tendon, allowing adaption to the defect as a malleable material.[4,5] INFUSE, a recombinant bone morphogenetic protein-2, has been shown to enhance the maturation of the graft it is combined with, accelerating guided bone regeneration with an increase in graft–bone contact.[6–8] Combination of the two materials allows maintenance of the grafted space as host angiogenesis occurs and stimulation of conversion to host bone. The graft is placed in enough volume to be equal to the ridge contour of the adjacent teeth. The procedure was repeated on the left incisor site (Figs. 14a & b). The flaps were closed with #6/0 nylon sutures in an interrupted pattern and the patient dismissed.

The patient returned four months after the graft placement, and a CBCT scan was taken to evaluate the graft and ridge contours in cross section (Figs. 15a & b). Local anaesthetic was again administered into the buccal vestibule and palatal aspects of the ridge at both planned surgical sites. The surgical guide that had previously been fabricated in-office was inserted intra-orally. A flapless surgical approach would be utilised. A 2.2 mm depth stop drill for the 3.9 mm guide sleeve of the appropriate length for the implant that was planned at each site was run through the surgical guide to depth. The surgical guide was removed, and a 2.0 mm direction indicator (DePlaque) was placed into each osteotomy and a periapical radiograph taken to confirm the planned osteotomy in relation to the adjacent teeth (Figs. 16a & 17a). The surgical guide was reinserted intra-orally, and the osteotomies were enlarged with consecutive 1.5–2.2 mm tapered depth stop drills of increasing lengths—6.0, 8.0, 10.0, 11.5, 13.0 and 15.0 mm—and then the next larger-diameter drill series was repeated with 2.0–2.8 mm depth stop drills and finally a 2.8 mm diameter drill was taken to 15.0 mm. The extra length was used to accommodate the 3 mm depth of the soft tissue using a flapless protocol. The two implants were placed utilising the guide sleeves to position them. The guide was removed, and 2 mm healing abutments were placed on both implants. A periapical radiograph was taken of both sites to document the depth and direction of the osteotomy prior to implant placement in relation to the adjacent teeth as well as the depth of the osteotomy in relation to the ridge crest (Figs. 16b & 17b). The patient was dismissed to allow for implant osseointegration.

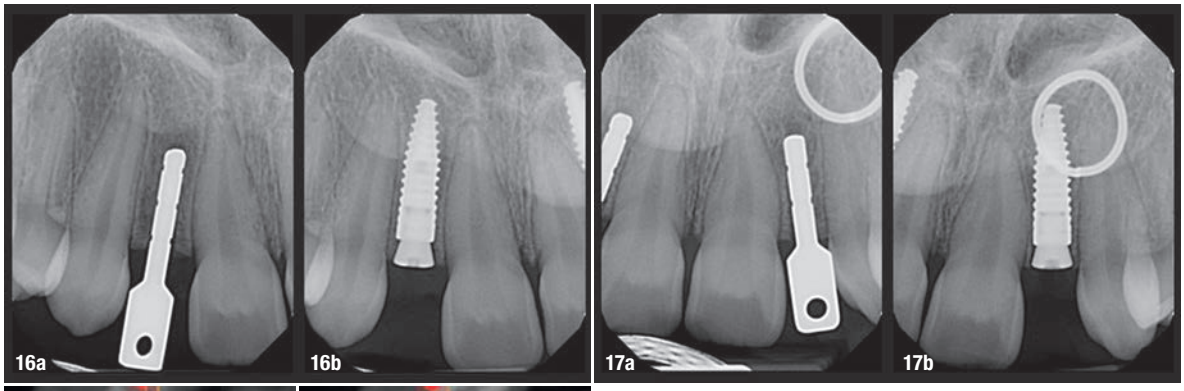


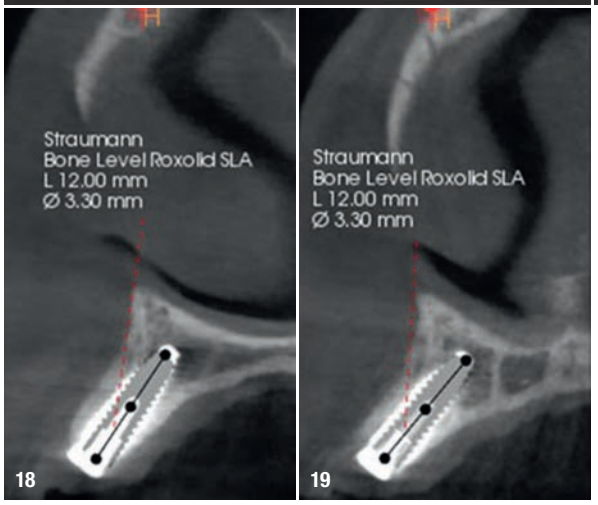
Figs. 15a & b: CBCT scan four months after grafting. Cross-sectional views to verify the contour of the ridge at the planned implant sites: right lateral site **(a)** and left lateral site **(b)**.

A post-surgical CBCT scan was taken and imported into the planning software. The virtual planned implant cross section was overlaid on to the cross section at the right lateral incisor to verify that the surgical guide had been able to achieve the planned position in relation to the osseous anatomy (Fig. 18). Both the planned position of the right lateral incisor and actual implant position were identical, demonstrating that the in-office surgical guide was accurate regarding the virtual planned position. Additionally, the facial aspect of the ridge where the graft had been placed eight months prior demonstrated sufficient thickness of bone for long-term implant maintenance. Evaluation of the left lateral site made similar findings, demonstrating the accuracy of the surgical guide in replicating the virtual planning (Fig. 19). Implant healing and integration were complete, and the restorative phase of treatment could be initiated.

Conclusion

CBCT scans increase the information available when planning implant placement by views that are not provided with traditional 2D radiographs. Utilisation of a diagnostic guide to take the CBCT scan increases the accuracy in the implant planning software, as it provides references to where the implants may be placed in the





Figs. 16a & b: Radiograph of the direction indicator placed into the right lateral incisor site after use of the initial 1.5–2.2 mm tapered drills **(a)** and radiograph following implant placement after the healing abutment was inserted on to the implant **(b)**. **Figs. 17a & b:** Radiograph of the direction indicator placed into the left lateral incisor site after use of the initial 1.5–2.2 mm tapered drills **(a)** and radiograph following implant placement after the healing abutment was inserted on to the implant **(b)**. **Fig. 18:** The virtual planned position cross section of the right lateral incisor overlaid on to the cross section of the actual implant placement, demonstrating clinical replication of virtual planning with the surgical guide. **Fig. 19:** The virtual planned position cross section of the left lateral incisor overlaid on to the cross section of the actual implant placement, demonstrating clinical replication of virtual planning with the surgical guide.

space that can be coordinated with the osseous anatomy. Corrections can then be made in in-office fabrication of the surgical guide that will be created on the cast used to create the diagnostic guide.

Congenitally missing lateral incisors pose challenges due to the limited facial–palatal dimensions of the ridge related to lack of development that would normally occur with tooth development at the site. CBCT planning allows cross-sectional viewing of the intended site to assess whether the width of the ridge will allow implant placement or supplemental grafting will need to be performed. Often in lateral sites with congenitally missing teeth, insufficient width is present, and grafting will need to be performed either in conjunction with implant placement or as a precursor to implant site osteotomy preparation. The case presented involved a ridge that would not allow initial implant stability at the sites, necessitating osseous grafting to improve the ridge dimensions and site healing before implant site preparation could be performed. The corrected surgical guide allowed planning in order to position the implant ideally for the anatomy, taking into consideration the triangle of bone in the premaxilla.

Editorial note: A list of references is available from the publisher.

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How clean do sterile implants have to be?

Analysis and clinical relevance of factory-related contaminations

Dr Dirk U. Duddeck, Germany

The initial phase of the biological response to a placed implant is primarily determined by the implant's surface characteristics. The properties of any implant surface are an essential factor of its non-irritant integration into surrounding tissue structures.[1] Undisturbed osteoblast proliferation and osteoblast differentiation at the implant surface depend decisively on the microstructure of the surface.[2] Since the 1980s, however, there have also been growing demands for flawless cleanliness of the implant systems used.[3] In this context, it is a logical step not only to look at current analytical techniques but also to take a critical look at the clinical significance of avoidable contamination on brand-new sterile-packaged implants.

SEM imaging

Imaging in the material contrast mode of a scanning electron microscope (SEM) has proved to be very useful for the analysis of particulate and film-like contaminants on sterile-packaged dental implants. Back-scattered electrons from the implant surface have typical energy of up to 10 keV. The intensity of these signals depends on the average atomic number of the sample material in focus. Compared with titanium or zirconium, heavier elements, such as iron or nickel, show more intense back scattering so that corresponding image areas appear bright (Fig. 1). In contrast, locations with lighter elements, such as carbonaceous plastic particles, are displayed darker than areas with titanium or zirconium (Fig. 2).

The image generated by the back-scattered electron detector thus allows conclusions regarding the distribution of foreign materials or elements in the imaged section of the implant surface. For a valid assessment of the particle load of an implant, a SEM image of the entire implant should always be acquired. In order

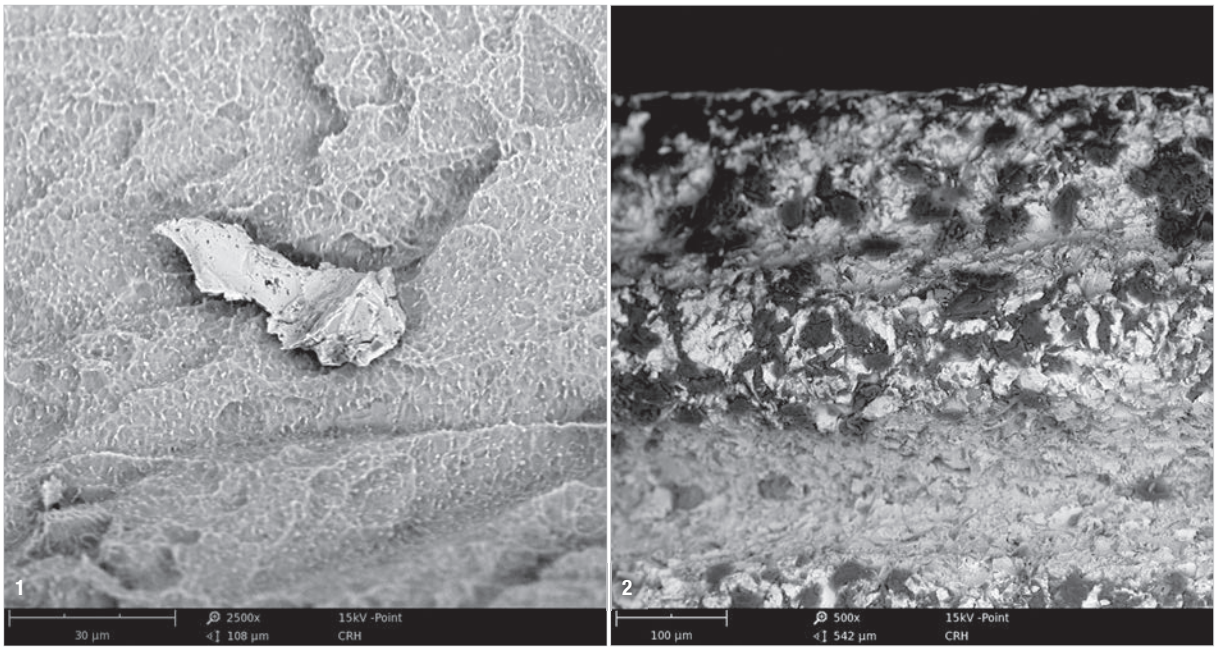

Fig. 1: Metal particle of iron, chromium and nickel on the surface of a titanium implant (Adin). SEM 2,500× magnification. **Fig. 2:** Numerous organic particles on the entire implant shoulder (OCO Biomedical). SEM 500× magnification.

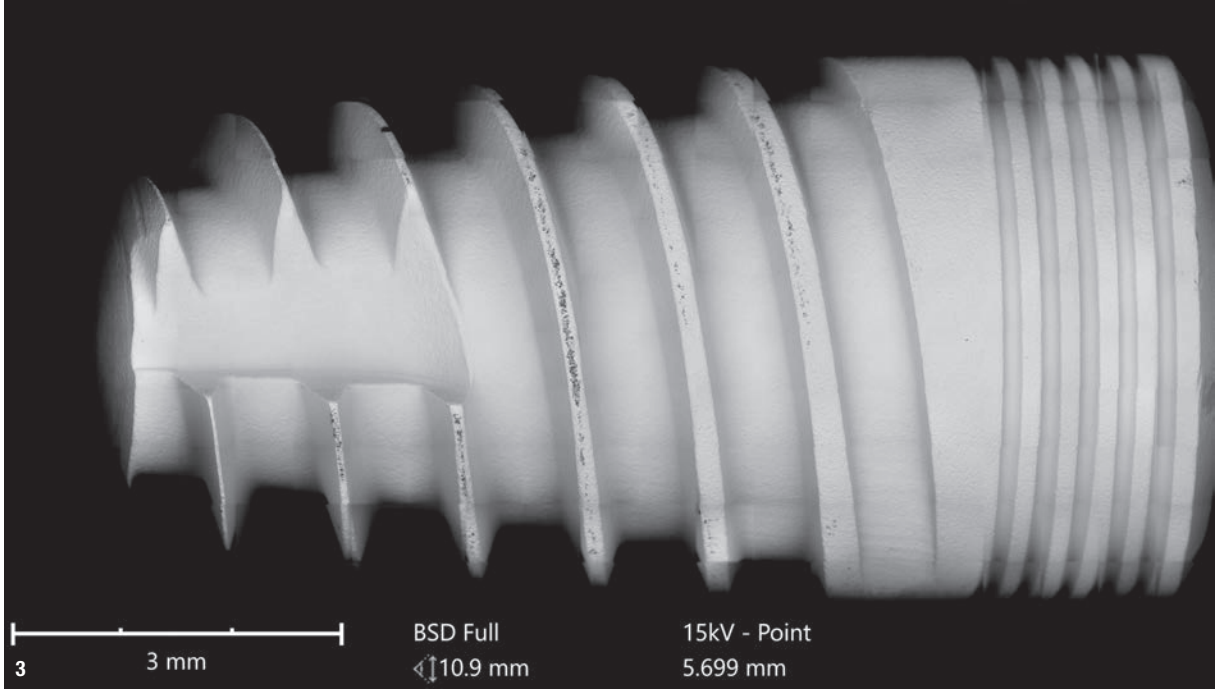

Fig. 3: Factory-related contamination of entire implant threads (Ritter Implants). Full-size SEM image of the implant electronically compiled from hundreds of single images at 500× magnification using the material contrast technique (back-scattered electron mode).

to depict details at high magnification without pixelation, up to 600 individual SEM images must be electronically stitched together in high resolution for these comprehensive overview images. The resulting SEM image in material contrast provides a detailed overview and allows the quantitative detection of individual particles (Fig. 3).

Identification of impurities

Energy-dispersive X-ray spectroscopy (EDS) provides information about the exact elemental composition of an impurity and thus provides hints about its origin. When fast electrons hit the sample surface, X-rays are emitted inter alia. The energy of these X-rays is characteristic of each chemical element present in the sample or contaminant. The energy and the number of X-ray quanta emitted in this way are measured over a defined time and output as an EDS spectrum.

Time-of-flight secondary ion mass spectrometry (ToF-SIMS) provides even more precise information about the chemical composition of an impurity. The method provides information on the atomic and molecular structure of the uppermost monolayers of a substrate on an analysis area of $500 \times 500\,\mu m^2$ with sensitivity in the parts per million range and a lateral resolution of up to 100 nm. Comparison of the spectra with known substances allows precise material determination of the respective contamination (Fig. 4).

Too many implants of inferior quality

In a study from 2017 to 2020, the CleanImplant Foundation, a non-profit organisation based in Berlin in Germany, analysed sterile-packaged implants from various manufacturers. In cooperation with Charité—Universitätsmedizin Berlin in Germany, a total of 14 ceramic implant systems and 86 implant systems made of titanium and its alloys were examined under the SEM. The protocol of analysis used in this quality assessment study was published in a 2019 pilot study by Duddeck et al.[4] The samples were examined for contaminants under the SEM in a testing laboratory accredited according to the DIN EN ISO/IEC 17025:2018 standard. For the study, the implants were unpacked in a particle-free environment (Class 5 clean room according to the DIN EN ISO 14644-1 standard) and subsequently scanned in the same clean room to exclude any laboratory interference with the test samples. To an unexpected extent, that is, in more than one-third of the samples examined, the analysis revealed factory-related residues and contamination. SEM imaging identified not only carbonaceous contaminants in significant quantities (Fig. 5) but also foreign metals such as chromium, iron, tungsten, nickel, copper and tin. Implants made of titanium and zirconium dioxide were affected, regardless of price, market position, size of the manufacturer or production location. Subsequent to the SEM/EDS analysis, selected contaminated implant samples were additionally examined by a detailed ToF-SIMS analysis. Polysiloxanes, that is, synthetic polymers (Fig. 6), thermoplastics and residues of dodecylbenzene sulphonic acid were found on the implant surfaces. This cytotoxic surface-active chemical is one of the most aggressive components in many cleaning agents and is classified as a hazardous substance.

Clinical relevance

In particular, organic carbonaceous foreign materials have been associated with initial bone loss or even peri-implantitis in the literature.[5] Increased osteoclast activity associated with a possible foreign-body reaction, resulting in peri-implant bone resorption, could be the cause.[6] Exposure to foreign particles induces macrophages to secrete tumour necrosis factor-α, interleukin-1β, interleukin-6 and prostaglandin E2, which in turn stimulates the differentiation of osteoclast precursors into mature osteoclasts. This response would explain clinically striking bone loss during the initial healing phase or the early onset of peri-implantitis. All particles found in the study

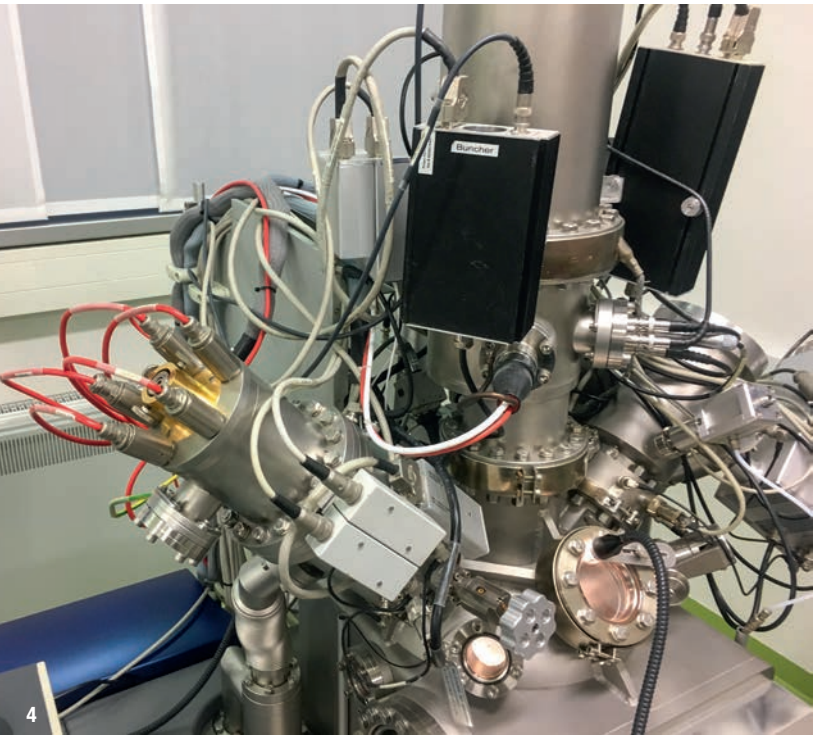

Fig. 4: Time-of-flight secondary ion mass spectrometry instrument (tascon).

appear to have survived the wet chemical cleaning procedures in the manufacturing process or contaminated the implant in the handling and packaging process. Especially foreign particles with a size of 0.2–7.2 µm are classified as pro-inflammatory.[7–9] If they detach from the surface during the insertion of the implant, macrophages take up the particles by phagocytosis and subsequently release pro-inflammatory cytokines. The result is an expanding zone of soft-tissue damage and inflammation.[6]

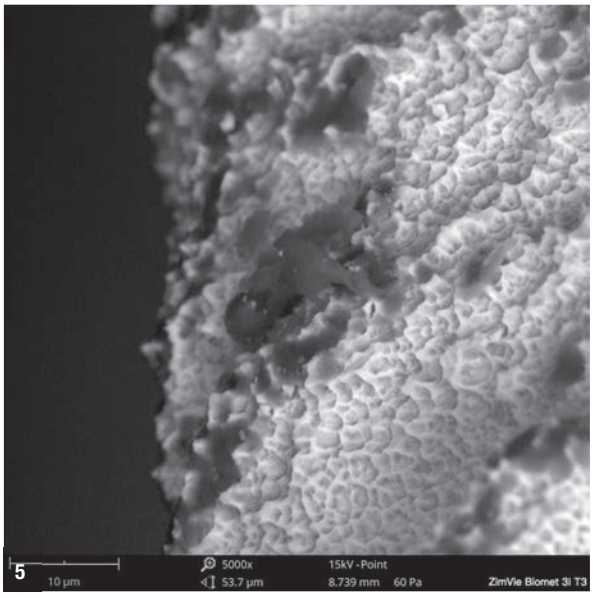

Fig. 5: Carbonaceous particles (polysiloxanes) on a titanium implant at the implant apex of a titanium implant (T3, ZimVie). SEM 500× magnification.

Independent test procedure provides safety for dentists

All implants examined in the recent quality assessment study, including those significantly contaminated, showed the CE mark on the packaging or carried the U.S. Food and Drug Administration logo for marketing clearance on the US market. With the introduction of a worldwide quality seal for clean implants, the "Trusted Quality" mark, the CleanImplant Foundation addressed this issue years ago. Criteria for implants that are largely free of foreign particles were defined in a guideline in 2017 and published as a consensus paper involving renowned scientists such as Prof. Tomas Albrektsson, Prof. Ann Wennerberg, Prof. Hugo de Bruyn, Prof. Florian Beuer, Prof. Jaafar Mouhyi, Dr Michael Norton, and Dr Luigi Canullo.[10] These scientists also form the foundation's scientific advisory board, which ultimately decides on the awarding of the above-mentioned quality seal. For the testing procedure of an implant system, a total of five samples are included. A maximum of three implants are obtained from the respective manufacturer and at least two implants from implantology practices. This procedure ensures random selection during sampling and reliably prevents the acquisition of potentially specially treated test samples. The independent and thorough analysis of the samples must be renewed every two years in specially accredited testing laboratories. The same protocol of analysis described in the *Journal of Clinical Medicine* in 2019 is to be applied.[4]

Before the seal can be awarded, proof of a multi-annual survival rate of at least 95% must be provided for the respective implant system, as well as proof of the absence of a significant number of particles. The results of the analysis and the sufficiently reliable clinical documentation of a system are always checked independently by two members of the scientific advisory board in a peer-review process and compared with the requirements of the guideline. Not until all criteria are met can an implant system be awarded the seal for a period of two years. To date, the following systems have been awarded the foundation's "Trusted Quality" seal after rigorous peer review (in alphabetical order): AnyRidge and BLUEDIAMOND (MegaGen), blueSKY (bredent medical), CONELOG (CAMLOG), ICX-PREMIUM (medentis medical), In-Kone (Global D), Kontact S (Biotech Dental), NobelActive (Nobel Biocare), Patent/BioWin! (Zircon Medical/Champions), Prama (Sweden & Martina), SDS1.2 and SDS2.2 (SDS Swiss Dental Solutions), T6 (NucleOSS) and UnicCa (BTI). Other implant systems are currently undergoing the testing process of the foundation.

Discussion

The evaluation of the CleanImplant quality assessment study revealed both light and shadow with regard to the current quality level and sustainable quality control of dental implants. This creates a problem for the careful

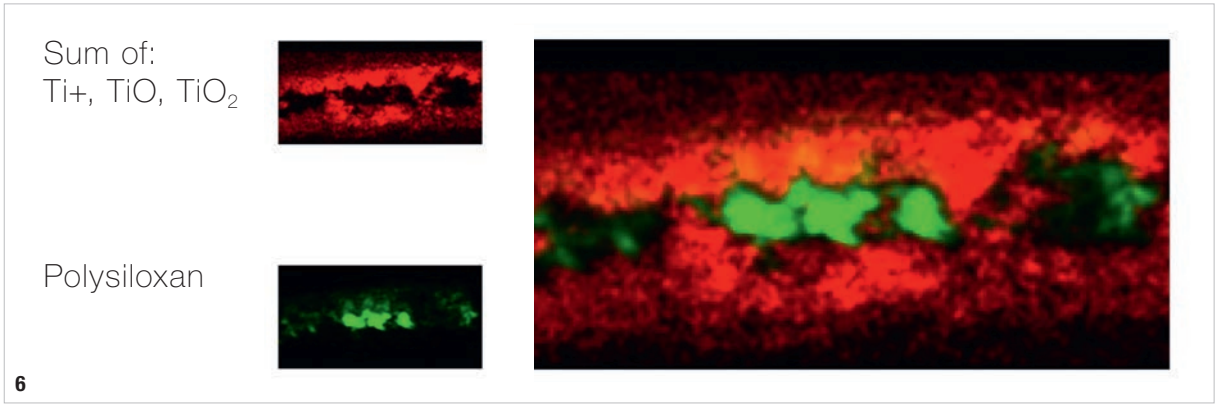

Fig. 6: Time-of-flight secondary ion mass spectrometry detection of polysiloxane on a titanium implant.

practitioner: he or she usually does not know whether the implant system of his or her choice has already been contaminated at the factory. This is because information or warnings about possible foreign particles that could cause peri-implantitis or about residues of cleaning agents is not provided on the implant packaging or on the package insert.

Fig. 7: Significant plastic material (polyacetal) on the shoulder of a ceramic implant (vitaclinical, VITA Zahnfabrik) from abrasion from the packaging.

Unfortunately, implant systems do not have consistent, comparable quality, as summarised in 2020 by Dr Norton, a past president of the Academy of Osseointegration, in an opinion piece in the *British Dental Journal* that is well worth reading.[11] The use of factory-contaminated implants not only may lead to inferior clinical outcomes but also carries the risk of legal implications. The problem of possible factory-related contamination concerns not only implants made of titanium or titanium alloys but also ceramic implants, as scientists from the universities of Gothenburg, Malmö and Berlin impressively described in a study published in 2021.[12] The bottom line of the study is that just because the material of ceramic implants is white does not necessarily mean that they are clean (Fig. 7). Suppose a clinician chooses a ceramic implant as a metal-free alternative and it has been demonstrably contaminated by packaging residues across batches. In that case, he or she is, unwittingly, doing a disservice to precisely those patients who place great value on particularly biocompatible materials in their bodies. In a remarkable article decades ago, Wahl and Tuschewitzki employed an apt term for factory contamination of dental implants: they referred to it as “sterile dirt”.[3]

Conclusion

The placement of foreign metals and packaging residues or cleaning agent residues in the osseous site of an implant can lead to an uncontrolled foreign-body reaction, resulting in bone recession and even the loss of implants. Contamination of sterile-packaged dental implants can be largely avoided by the manufacturer. However, if individual manufacturers, when asked, say that they consider the amounts of foreign particles found on their products to be harmless according to their own judgement, it would be appropriate for them either to scientifically verify this or to warn users and patients accordingly.

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about

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Digital dental shade measurement: Practical applications with a state-of-the-art colorimeter

Dr Jordi Manauta, Dr Walter Devoto, Daniele Rondoni, Dr Anna Salat, Prof. Zsolt M. Kovacs & Prof. Angelo Putignano, Italy/Hungary/Spain

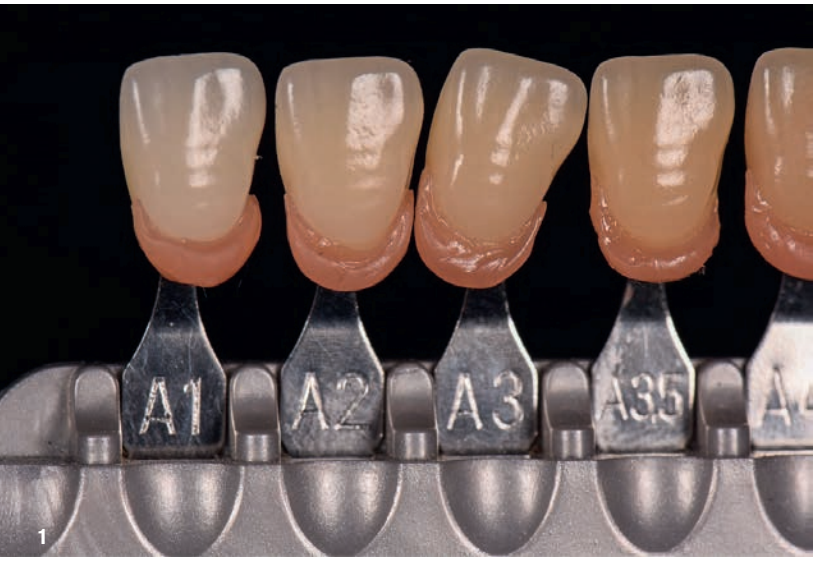

Fig. 1: VITA classical A1–D4 shade guide with the pink additions to improve its contextuality and increase its efficiency in shade matching.

Introduction

In its vast complexity, colour science embraces physics, mathematics, geometry, measurement, perception, chemistry, optics, art and human psychology, among many others. In a nutshell, colour is psychophysics. Misinterpreted colour science concepts and their incorrect application are often found in the dental literature. It is often difficult to explain complex colour science concepts relevant to the dental field using easily understandable words. In the following pages, we will try to translate some of these concepts to more easily understandable language.

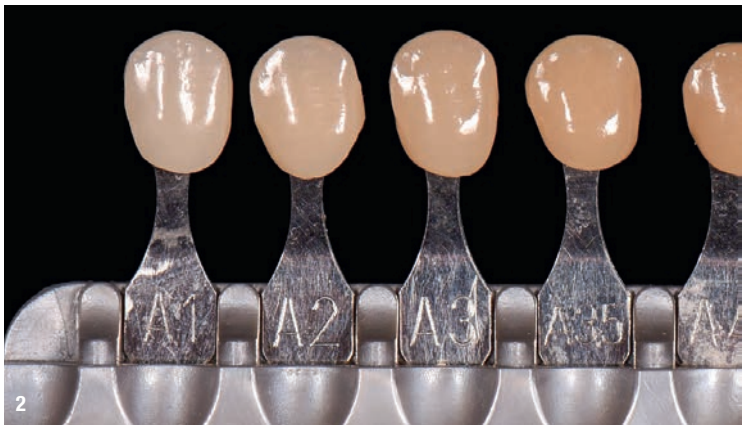

Fig. 2: VITA classical A1–D4 shade guide with the cervical and incisal portions trimmed.

Dental shade determination is very important and requires extreme precision in measurement, computing and execution; in other words, the definitive restoration has to be perfect to the eye of the clinician, technician and patient. This task can be done digitally or analogically.

Shade determination by eye is, for obvious reasons, the most commonly used shade taking method among clinicians. Despite this, the scientific community seems not to appreciate it, owing to its lack of objectivity, as several factors can affect the way we perceive dental shade. However, it has the advantage of being the ultimate means of judging dental shade regardless of the shade determination method used, since what matters the most is the appearance of the definitive restoration in place.

Despite being available for more than 30 years, digital shade determination methods only became popular when their measurements found application in clinical and laboratory situations. Without digital shade determination having a true benefit in clinical outcome, dentists and technicians have tended to rely on shade determination by eye.

Dental shade guides

For a very long time, stock shade guides have been the first resource for dental shade determination, and for several reasons, there has always been an excuse to improve them or a hack to make them more reliable. The VITA classical A1–D4 shade guide (VITA Zahnfabrik) has always been the default whenever other methods have not worked. VITA shade matching has always been

linked to artistic skills and a deep knowledge of the materials and their specific instruments, such as shade guides.

Common do-it-yourself (DIY) strategies have been proposed throughout the years, in order to optimise the use of stock shade guides. For example, adding an increment of pink composite gives the shade guide a more realistic context, making the sample look more like a real tooth emerging from the gingiva (Fig. 1). Although this does not solve the core issue of stock shade guides, it slightly helps focus attention on the full tooth. However, this hack has had limited success. Commercial pink shade guide holders of various brands have been proposed to this end, but they are easily fabricated by any clinician with acrylic resin.

Another DIY method aiming to optimise stock shade guides and increase shade matching precision is trimming of the cervical and incisal portions (Fig. 2), leaving only the area where the shade is more even throughout the surface. This eliminates all distractions in shade matching, as for many people, the translucent mass in the incisal area and the opaquer cervical area are distracting rather than helpful. This area trimming makes the shade samples look more like they are of solid shades. This hack not only has had limited success but also gives rise to other problems, one of which is that the useful area of shade reference, which is the centre of the shade guide, is significantly decreased.

Personalised shade guides are easy to self-manufacture using the same materials as those used for the actual intra-oral restoration. These have been proposed as the ultimate solution, but have several problems. The first problem is not related to the shade guide itself but to the end user. Self-fabricating several samples is time-consuming for most users, especially if one considers

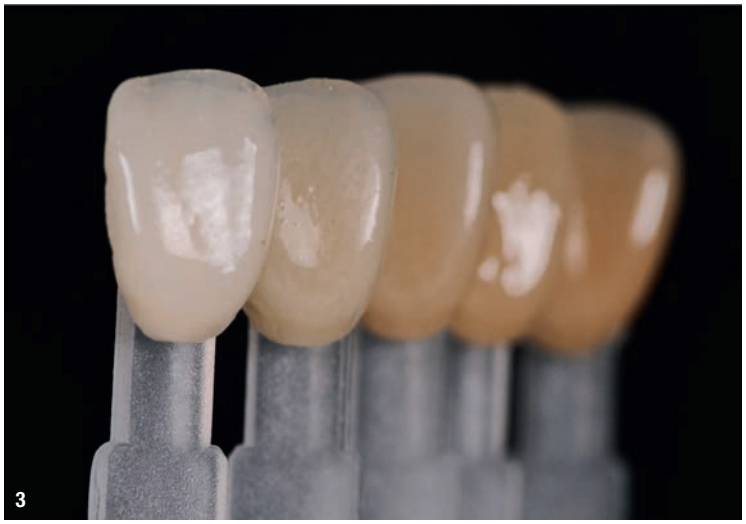

Fig. 3: Two-layer personalised shade guide. This makes composite layering more predictable, but has limitations and some problems.

the high number of sample combinations required for a functional sample set, explaining the success of standard shade guides such as the VITA shade guide, which require little to no handling before use. Making a perfect personalised shade guide (bubble-free, of adequate thickness and of uncontaminated composite) requires skill and experience, regardless of the personalised shade guide system used, to obtain perfect shade correspondence with the stock shade guide and to avoid discrepancies with the definitive restoration (Fig. 3). The personalised shade guide tends to be of different thickness compared with that of the actual restoration, changing the real shade and perceived shade greatly, and thus obtaining poor shade matching for both ceramic and composite restorations (Fig. 4). Furthermore, personalised shade guides lack context, since there is no gingiva or neighbouring teeth, changing the optical appearance.

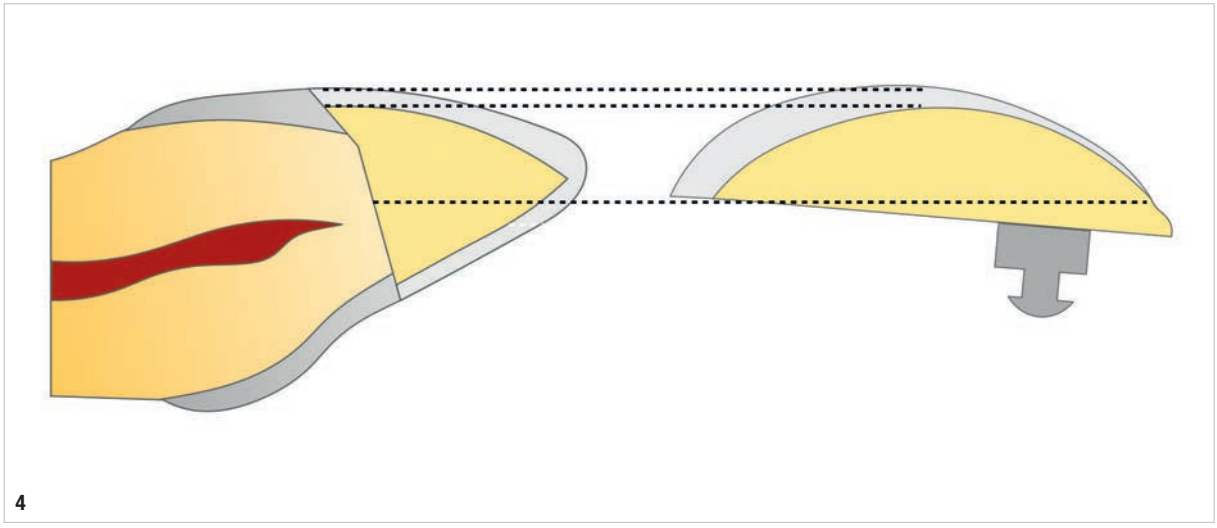

Fig. 4: Thickness of the personalised shade guide compared with ideal thickness in an intra-oral restoration. The thickness is not matched optimally.

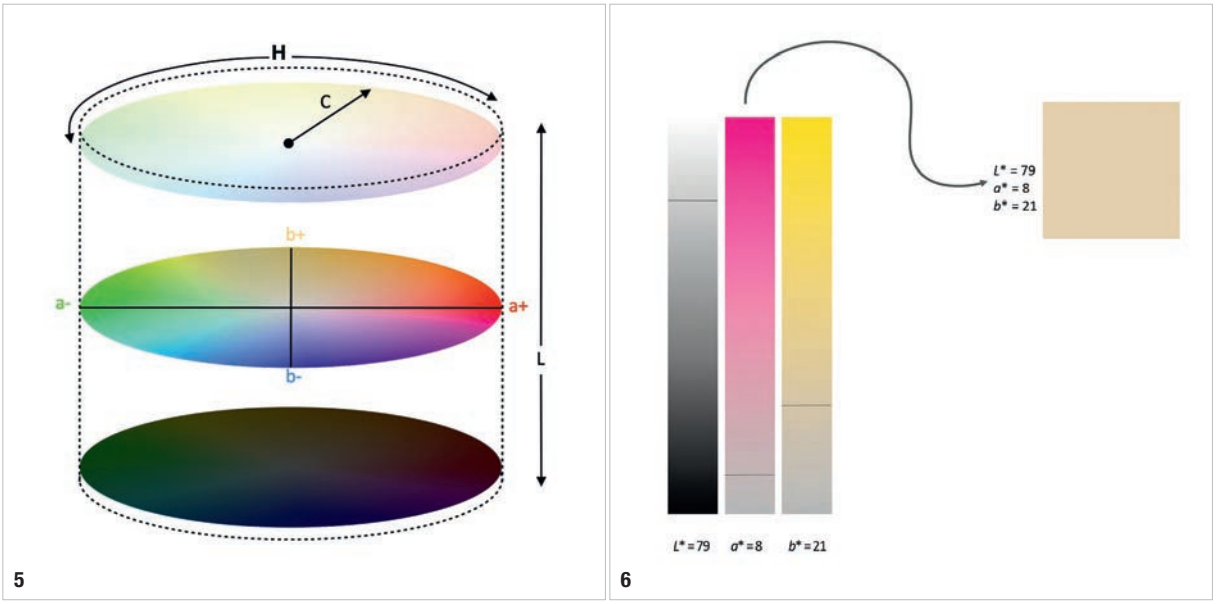

Fig. 5: The *L*a*b** colour space. *L* = light–dark, *a*– = green; *a*+ = red; *b*– = blue; *b*+ = yellow. *L* = light–dark and *L*C*h** color space where *L* = light–dark, *C* = chroma, *h* = hue expressed in degrees. **Fig. 6:** Graphic representation. (albeit highly inaccurate) for didactical purposes, of the colour mixture of the *L*a*b** dimensions to obtain a dental shade (i.e. A3).

Why switch to digital colorimetry?

It is impossible to precisely transfer complete information about shade using words because the perception of even a very specific shade differs between people. Digital colorimetry has many advantages compared with the visual method:

– clear and objective language;
– context of neighbouring structures;
– every high repeatability;
– simplicity in obtaining measurements; and
– ease of standardisation.

The *L*a*b** colour space overcomes language barriers, enabling anyone to easily communicate shade and shade differences (Fig. 5). The *L** axis runs from light to dark, 100 being white and 0 black. The *a** axis runs from red to green, a positive value indicating red and a negative value green. The *b** axis runs from yellow to blue, a positive value indicating yellow and a negative value blue.

When graphically located in the full *L*a*b** colour space, the human dental colour space looks like a small irregular-shaped bean (Figs. 6–8). This sub-space is extremely important for our profession. It is mainly

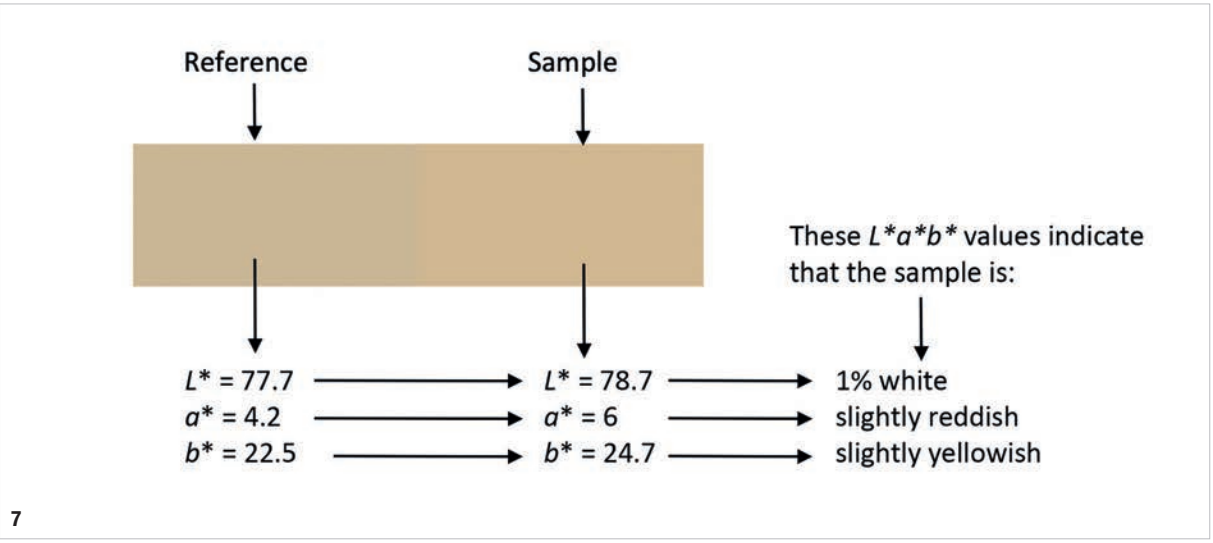

Fig. 7: Matching the reference shade against the sample shade.

located in the yellow–red and bright area and is very low on chromaticity, touching the neutral axis in almost all of its spectrum. This space is composed of very light beige pastel colours.

Rizzi et al. outlined the human dental colour sub-space.[1] They found that the best colour difference formula that behaves the most isotropically and uniformly along all axes of this sub-space was the formula ΔE_{94}.[1] For digital colorimetry, knowing the content and boundaries of the dental colour space precisely makes the design of the machinery, calculations of layering and ceramic mixing, calibration of the shade measuring devices and hardware specifications more specific.

OPTISHADE StyleItaliano

Nowadays, it is easy to determine dental shade in a few seconds with a very compact and portable device, OPTISHADE StyleItaliano (Smile Line), and in an incredibly easy way that is not dependent on the clinician's skills. Learning how to use the device is easy and can be done by the dentist, the assistant or the technician, simplifying the work of every member of the team.

The OPTISHADE StyleItaliano colorimeter was launched in 2021 specifically for dental application. It works with Apple devices via an app and can be disinfected (Fig. 9). Its high precision (ΔE_{94}: 0.2–0.4) and accuracy in shade measurement in the *L*a*b** and *L*C*h* colour spaces allow for real-time cross-checking of data with several preloaded shade guides, such as the VITA classical A1–D4 shade guide and VITA Toothguide 3D-MASTER.

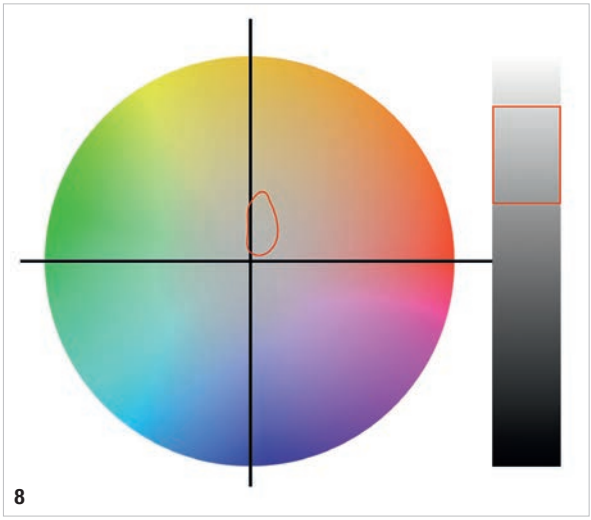

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Fig. 8: When graphically located in the full *L*a*b** colour space, the dental colour space looks like a small irregular-shaped bean.

In an era in which communication is crucial, this device exploits the complete sharing capability of modern mobile devices. In a matter of seconds, it is possible to measure the shade of a tooth and communicate the shade measurement to others, all with the safety and stability of the Apple platforms.

Shade matching by replicating the same scenario

When we have an accurate and reliable method for shade matching, we should obtain the same numerical values when measuring the same subject. Our task consists of repeating the same scenario for

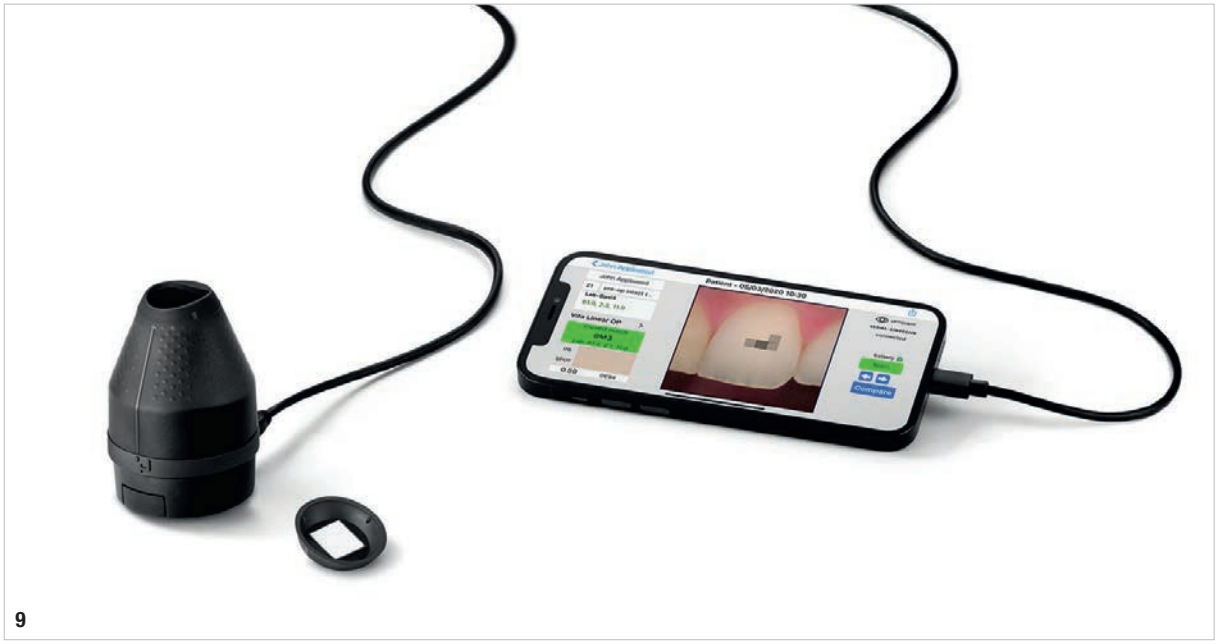

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Fig. 9: The OPTISHADE StyleItaliano dental colorimeter provides accurate and precise shade measurements. The external camera attaches to Apple devices.

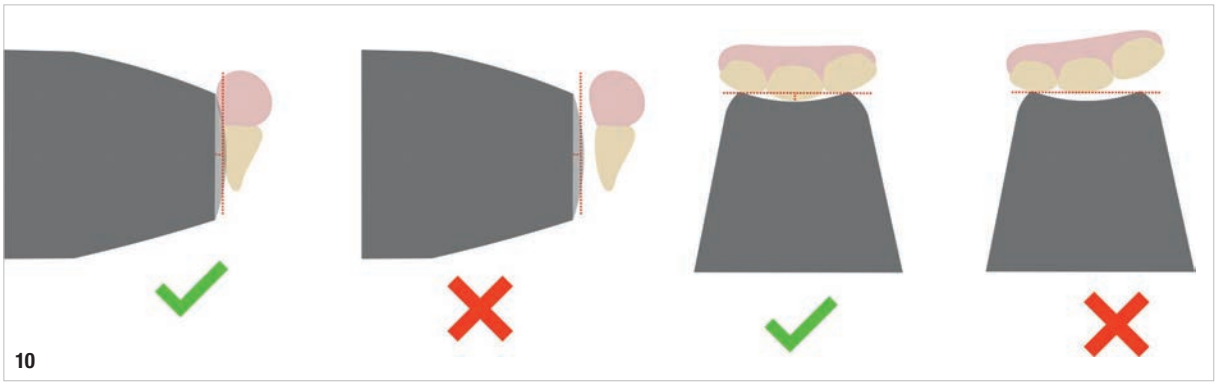


Fig. 10: Scene reproduction in practical application.

every measurement; in other words, shade should be measured using a device that has minimal discrepancy in its measurements (intra-device precision) and minimal discrepancy compared with other devices of its kind (inter-device precision), with the same background and centring and positioning, with the teeth clean and hydrated, and with no external light contamination.

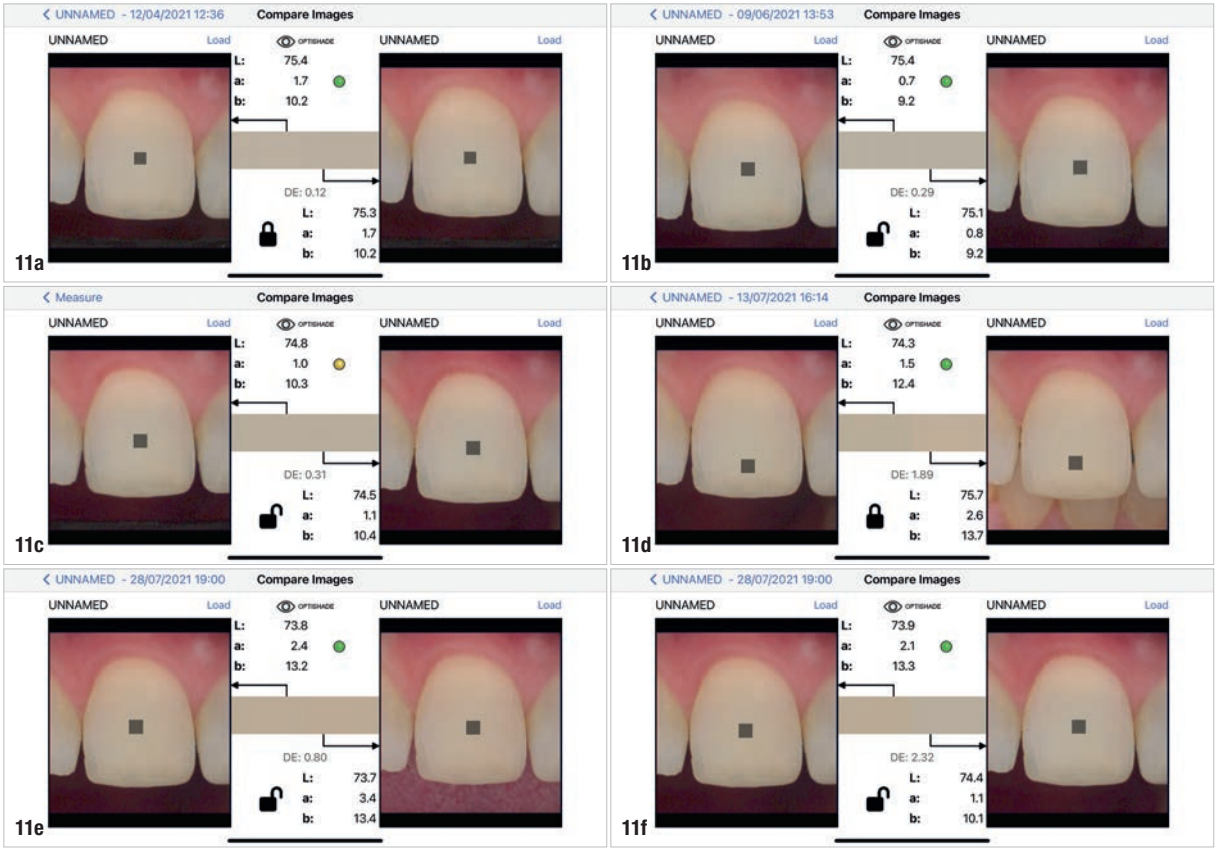


Fig. 11a: Same tooth, same surface (clean), same time frame, same positioning, same device, same background. Shade difference: 0.12. Reliable measurement. **Fig. 11b:** Same tooth, same surface (clean), *different time frame, same positioning, same device, same background. Shade difference: 0.29. Reliable measurement. The asterisk indicates the parameter critical to the reliability of the measurement. **Fig. 11c:** Same tooth, same surface (clean), *different time frame, same positioning, *different device, same background. Shade difference: 0.31. Reliable measurement. The asterisks indicate the parameters critical to the reliability of the measurement. **Fig. 11d:** Same tooth, same surface (clean), same time frame, same positioning, same device, *different background. Shade difference: 1.89. Unreliable measurement. The asterisk indicates the parameter critical to the reliability of the measurement. **Fig. 11e:** Same tooth, same surface (clean), same time frame, same positioning, same device, *different background. Shade difference: 0.89. Unreliable measurement. The asterisk indicates the parameter critical to the reliability of the measurement. **Fig. 11f:** Same tooth, *different surface (not clean), same time frame, same positioning, same device, same background. Shade difference: 2.32. Unreliable measurement. The asterisk indicates the parameter critical to the reliability of the measurement.

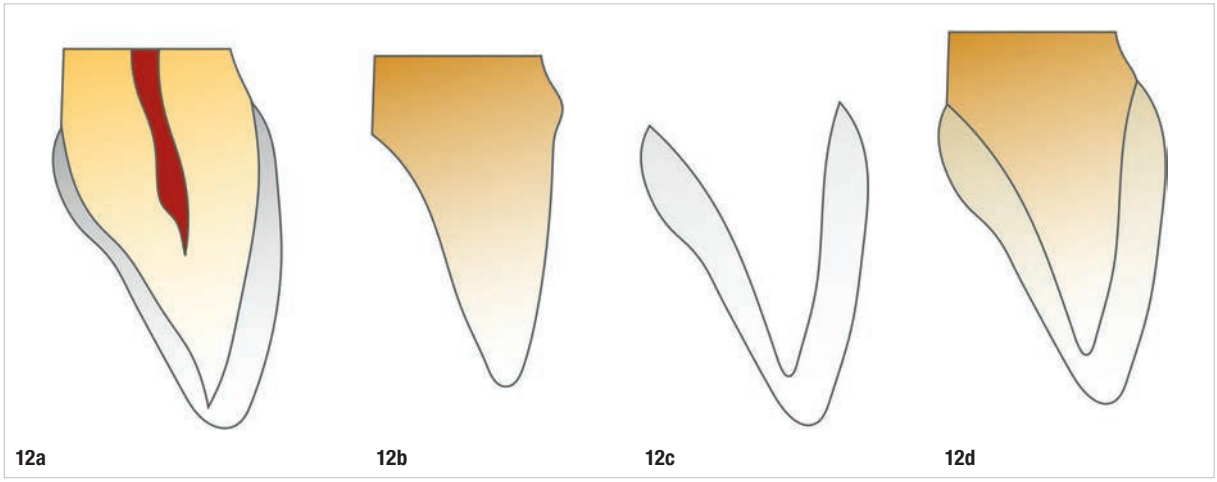


Fig. 12: Ceramic layering predictions: desired shade **(a)**, substrate **(b)**, raw restoration **(c)**, restoration integrated with the substrate **(d)**.

With these simple parameters, it is possible to reproduce the scene accurately and obtain a reliable shade measurement (Fig. 10). The user should be able to easily recreate the same scene. When measurements are taken from the same subject, the resulting values must fall under a 0.4 ΔE_{94} threshold. If measurements with higher values are obtained, it is necessary to analyse what may have gone wrong in the standardisation process, such as the tooth background, device positioning, tooth cleaning or tooth hydration level (Figs. 11a–f).

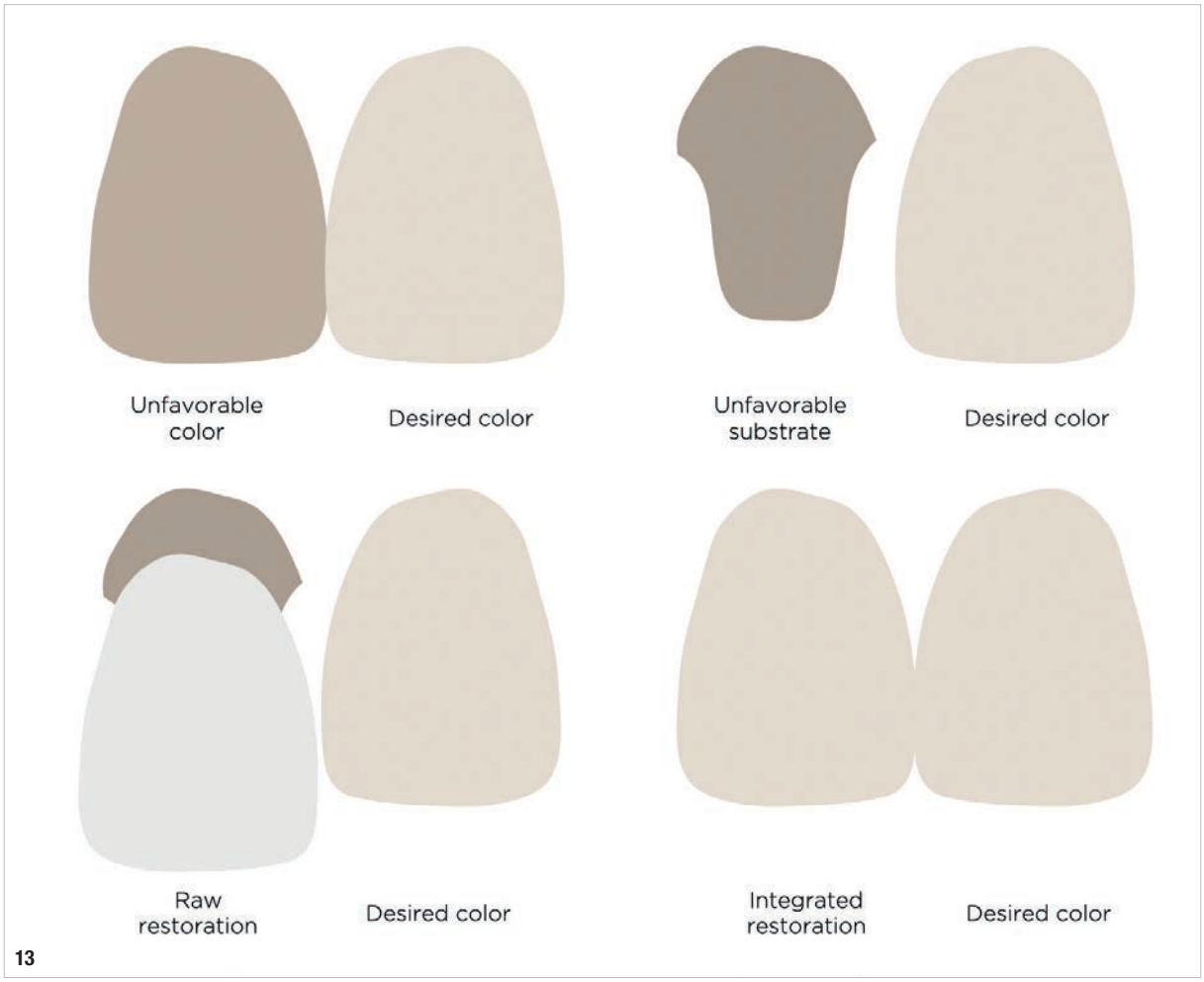


Fig. 13: Obtaining a good shade match for the integrated restoration.

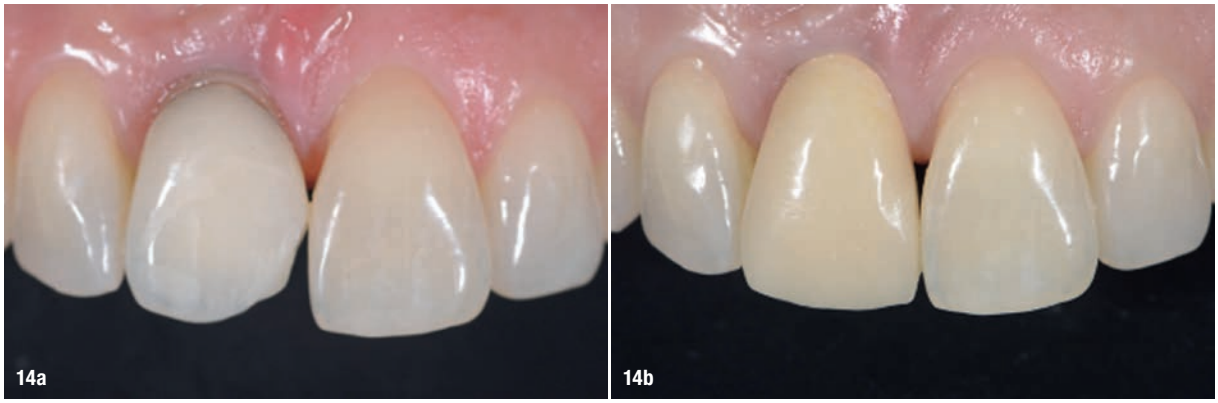


Fig. 14a: Failed anterior crown. **Fig. 14b:** Acrylic temporary restoration.

Digital ceramic mixing and layering predictions

Among the applications for OPTISHADE are ceramic layering and mixing predictions, composite layering recipe calculations, bleaching tracking and material quality control, to mention just a few. To make the system more versatile, OPTISHADE is compatible with an integral ceramic mixing and layering system (Matisse) in such a way that the personalisation and shade matching of the aesthetic restorations and ceramic prosthetic work reach perfection.

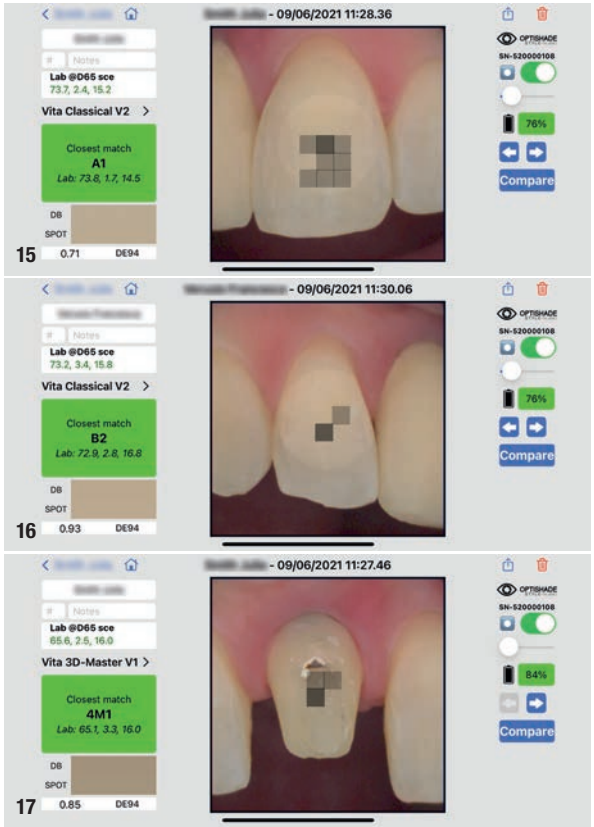


Fig. 15: Desired shade (neighbouring tooth). **Fig. 16:** Measurement of the shade of the maxillary lateral incisor. **Fig. 17:** Taking the shade of the prepared tooth into account.

One of the greatest challenges in dental shade is the integration of the single-unit anterior restoration. This has been demonstrated to be very reliable when done with precise mathematical computation, particularly with ceramic mixing and layering.

For the best outcome of ceramic mixing and layering software predictions, it is essential to use a high-precision shade matching device. OPTISHADE has been demonstrated to be the best for this application. Two perfect shade measurements must be provided (Fig. 12):

- Desired shade: This is the target shade. It is calculated from the nearby healthy teeth or nearby attractive restorations.
- Substrate shade: This is the shade of the prepared tooth to which the restoration will be cemented. Since this may modify the final shade of the restoration, it must be considered.

With all this information, it is possible to calculate several layers of a restoration that, together with the stump, will generate a final shade. The raw restoration, that is, before integration and in-context try-in, has a different appearance from the desired shade. It is out of context and thus without the influence of the substrate. With the raw restoration, it is possible to modify the unfavourable substrate to be very similar or equal to the desired shade. The shade of the raw restoration is calculated mathematically, in order to obtain the right layers and opacities to balance the chromatic change that will occur when the restoration and substrate are integrated. The integrated restoration, that is, the restoration seated on the substrate in the mouth, whether permanently cemented or attached with a try-in agent, must have the desired shade as a final result or at least be very close to it (Fig. 13).

Single anterior crown: A clinical case

Probably the application where digital shade determination stands out and is the most useful is in the creation of single aesthetic crowns in the anterior region. In this

Table 1

Substructure	Dentine receipes	Skin enamel (aprismatic enamel)
Substructure material IPS e.max Press HO 0		
Thickness of framework 0.3 mm (cervical area) 0.3 mm (middle area) 0.3 mm (incisal area)		
Instructions Stain the framework by making changes to red (*a**) or yellow (*b**)		
Estimated required staining $\Delta a^*=1.77$; $\Delta b^*=11.03$ (cervical area) $\Delta a^*=2.28$; $\Delta b^*=7.61$ (middle area) $\Delta a^*=1.09$; $\Delta b^*=1.53$ (incisal area)		
Estimated required staining with VITA Toothguide 3D-Master 2M1 (cervical area) 1M1 (middle area) OM1 (incisal area)		
	Cervical area IPS e.max Ceram D3 x3 IPS e.max Ceram PB L4 x6 Mamelon salmon x1	**Cervical area** IPS e.max Ceram Power Incisal 2
	Middle area IPS e.max Ceram CT orange x1 IPS e.max Ceram White-blue x1	**Middle area** IPS e.max Ceram Power Incisal 3
	Incisal area IPS e.max Opal Effect 4 x2 IPS e.max Ceram D C1 x3	**Incisal area** IPS e.max Ceram Power Incisal 3

Fig. 18: Shade selection of the different regions in Matisse. In red, the three regions of the desired shade (dentinal shade). In blue, the three regions of the preparation shade. **Table 1:** Ceramic mixing strategy for a perfect personalised recipe. The numbers in blue indicate the units for mixing, where a unit is the minimal amount of ceramic to be mixed. Units can be large or small as long as all the units are the same. Use of a quality ceramic portioner is recommended.

clinical case, the crown on implant #11 had failed mechanically and aesthetically (Fig. 14a). The ideal situation for such a case is to restore it in a single try, without the technician ever seeing the patient and of course avoiding any kind of repetition. This can be achieved by providing the OPTISHADE measurements of the desired shade and the stump shade (Fig. 14b).

The desired shade in this case was found in the neighbouring tooth. It is important to have the measurement done with the temporary restoration seated and the tooth perfectly hydrated (Fig. 15). The shade of the maxillary lateral incisor was also measured (Fig. 16). The teeth in the same arch might look similar or even identical, but they are generally of different shades. The shade of the stump has to be taken into consideration, using an individual measurement that is included in the calculations for the restoration (Fig. 17).

The OPTISHADE shade measurements are uploaded to Matisse, and these, along with the type of restoration, are crucial for planning a perfect raw restoration (Fig. 18). Thereafter, the ceramic is mixed according to a perfect personalised recipe provided by Matisse (Table 1). The definitive crown showed very good integration (Fig. 19). This was achieved in only one attempt.

Conclusion

Digital shade determination removes the subjectivity of the eye. As long as the measurement is correctly taken, the colorimeter cannot be fooled like the human eye can. Communication using numbers is the most precise way to define a shade. With precise data, we can calculate ceramic mixing, layering and much more. The new technologies mentioned in this article, besides being precise, are now more user-friendly, allow easy sharing and saving of data, are more universal and do not require any hardware updates.

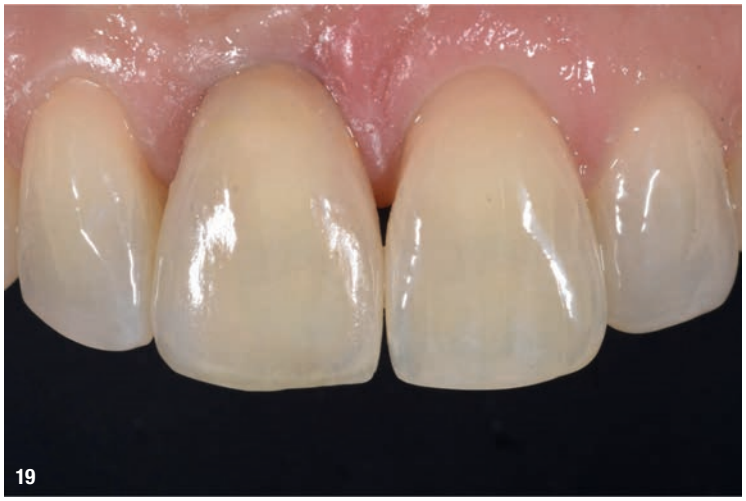


Fig. 19: Definitive crown.

contact

Prof. Angelo Putignano is currently head of the department of restorative dentistry and endodontics and dean of the school of dentistry at the Università Politecnica delle Marche in Ancona in Italy. He is a co-founder of the StyleItaliano community. He can be contacted at: infocourses@styleitaliano.com.

The real cost of an analogue impression, compared with a digital one

Dr Naren Rajan, USA

Digital dentistry is a major cost, and a sound investment is dependent on realistic return on investment (ROI) planning. What sort of offset costs can be achieved? Can you match your ROI with patient care?

Thousands of dentists have already put intra-oral scanning equipment through its paces—day in and day out. I've been asked to reflect on the following question: was it worth spending the money when you bought into digital impression technology?

Fig. 1: Comparison of polyvinyl cost versus scanner cost. The cost saving reflects the saving on polyvinyl only. It does not include staff time, staff efficiency, shipping savings or increased revenue due to higher case acceptance. This cost offset calculation is just an example. Please contact your local 3Shape reseller for financing options.

The financial impact of digital impressions on my business

I think that from a financial standpoint, for restorative dentistry, the greatest advantage was the efficiency of utilising our team members in the office. Many obligated duties for managing the physical impressions were essentially gone overnight! Before, we were taking impressions all day long, and there was a team member whose responsibility was to disinfect the impressions and manage the prescription slips, the shipping, the return date, pouring the opposing models and whatnot. Simply not having to do that directly equates to a significant savings because we can now manage that team member's time more efficiently. That team member can move on to the next patient.

There is no extra laboratory work that needs to be done before the end of the day, no racing to the UPS or the FedEx box. We noticed that right away, and that is one of the prime advantages of moving to intra-oral scanning for a dentist who is not currently doing so.

The bulk of savings is in laboratory turnaround time

The second thing is the improvement in turnaround time with the laboratories. Before, we would routinely wait for two full weeks for a restoration to come back to our office. The dental office is based on the East Coast of the US, but often we use laboratories on the West Coast.

Now, if I scan, say, on a Monday morning, the restoration arrives on Wednesday morning for that model. For our routine procedure, which is between one and three units, we produce all of them without any physical models.

Taking advantage of the digital workflow in that way has really helped the efficiency of our practice and our business. I shared that feedback a couple of years ago with 3Shape when the company was working on the ROI calculator: that is the bulk of the financial savings that I can attribute to the TRIOS. These financial benefits can be gained by any dentist within the first couple of months.

What growth to expect after starting with intra-oral scanning

I know that our clinic has grown every year since we have introduced this technology and that there is a component of the incorporation of this technology that is part of that growth. I share that information with dentists in my area. I could figure out percentages for my own clinic, but I can tell you from patient visits that I think we are more productive actually. I am working more days now, coming out of the pandemic, but prior to the pandemic, I was working fewer clinical days but producing more revenue than I had in the previous years.

My most enjoyable year in practice was 2019, prior to the current world difficulties, when we really were firing on all cylinders by incorporating this technology. We were doing at least one to two reconstructive cases digitally per month, and it was a very enjoyable way to practice and it was profitable.

Using the technology goes far beyond just an impression replacement when you look at the ROI calculator, but even if the dentist is only focused on acquiring the TRIOS as an impression replacement, it can be asserted that buying a TRIOS will save him or her money.

My experience with offsetting costs when purchasing my dental 3D scanner

In my one-dentist clinic, I was spending about US$500 or US$600 a month on polyvinyl impression material prior to buying a scanner. When I bought my first scanner, the TRIOS 2, I think the payment on the scanner was US$700 or US$800 a month. Thus, there was already a cost offset from not having to buy the polyvinyl (Fig. 1). A dentist considering acquiring the technology has to figure out what it is going to cost per month, because most dentists are going to finance it through their reseller. The subscription cost also needs to be added on top of that.

In some cases, the dentist may be spending a few dollars more on his or her TRIOS investment, initially at least. However, this does not consider the cost savings of the time benefits that I mentioned, the savings from utilising the team with greater efficiency, rather than spending payroll on a team member pouring models and making UPS labels and things like that. When the dentist first introduces the scanner, it is almost a one-to-one transfer, and I do not think it will cost the dentist any extra to move to this technology, but then as he or she really starts utilising it and leveraging the other tools that are included, that is when he or she will really start to see many of the advancements and the savings—the true ROI.

The time you spend as a dentist is a key cost factor

If I was looking at this afresh, it would be difficult to imagine that buying this piece of technology would save me US$100,000, US$200,000, US$300,000. However, from the experience that I have had, I know that it has saved me money and that it has helped grow my practice and my reputation in the dental community.

How my team adjusted to the new impression technology

My dental assistant is over 60, and she has been in dental assisting for 40 years. She was able to pick up this technology within the first couple of months. She manages the calibration and the 3Shape Dental Desktop platform, she handles the management of case orders on a daily basis, and she can copy and edit orders and things like this. She was able to learn how to use the system, and she is a more experienced person with a vast analogue background.

It is very easy to use and share data. When patients come in, we will take the smile design photographs, and I will bring these into TRIOS Smile Design and see whether the gingival levels are where we want them or see whether the crowns are where we want them. I take screenshots of this or short videos and send these to the orthodontist. The orthodontist is always pleased with the level of data I provide and with the level of communication with patients enabled by this technology.

about

Dr Naren Rajan, who graduated with honours from Rutgers School of Dental Medicine in Newark in New Jersey in the US, is a leader in the education of digital techniques in dentistry and lectures nationally on the topic. In practice for over 15 years, Dr Rajan focuses on incorporating digital techniques into all aspects of general practice. He believes in finding the best combination of traditional techniques and cutting-edge advancements to improve patient outcomes.

Review of Aoralscan 3

The latest intra-oral scanner by SHINING 3D—the best low-cost intra-oral scanner?

Dr Ahmad al-Hassiny, New Zealand

Figs. 1 & 2: Aoralscan 3 is one of the smallest scanners on the market.

Aoralscan 3 was released on 12 September 2021. It is an affordable, scanner-only device, but comes with much better software than most Chinese intra-oral scanners (IOSs) that the Institute of Digital Dentistry in New Zealand has reviewed—in fact, better software than many mainstream scanners too.

Scanning speed

Aoralscan 3 is a high-performance scanner. It is very fast and provides a smooth scanning experience. It can be considered one of the best Chinese scanners on the market. The scanning process is efficient, and the artificial intelligence (AI) is excellent.

This scanner has impressive scanning speeds, especially given its very low cost. Considering scanning speed alone, it competes with much more expensive scanners on the market, such as Medit i700, TRIOS and iTero. We achieved full-arch scans easily within 30–35 seconds.

It is equipped with intelligent algorithms to make the scanning process easier and faster. Soft tissue is removed automatically and accurately, and bite registrations are fast. The scanner quickly finds its place again when the scanning is paused and restarted.

There are no loading screens between each scanning stage during the scanning workflow, making the workflow fast and efficient. Very brief processing occurs when switching between jaw scans, but this is barely noticeable. Instead, the majority of the processing occurs after all scans have been completed. This final post-processing took about 3–5 minutes for most cases, which is about average across all scanners, on our high-performance laptop.

Scanner size and ergonomics

Aoralscan 3 is super-ergonomic and a huge improvement on the Aoralscan 2. It fits comfortably in the user's hand and has a narrow scanning tip that makes it enjoyable to scan with.

The scanner weighs 240 g, making it one of the lighter scanners on the market. Having dimensions of 281 × 33 × 46 mm, it is one of the smallest IOSs on the market in 2022 (Figs. 1 & 2).

The scanner has some excellent added benefits, such as a remote control function built into the scanner using a motion detector, similar to Medit i700 and TRIOS. The remote control feature is well executed in the software. This feature enables navigation of the software without touching the computer, and it is effortless. The user double-clicks the scanner button to progress through the workflow (jaw scans) or clicks and holds the button to access a pop-up menu with four options—"next", "back", "delete" or "view the model"—and choses the desired option by waving the scanner in one of four directions.

Full-arch scanning

Aoralscan 3 handles full-arch scans very well. It has an impressive scanning speed, impressive AI and an inbuilt fan that prevents fogging and enables long periods of uninterrupted scanning. The scanner picks up when it is stopped quickly and is used with a similar scanning protocol to all other scanners.

Accuracy

Regarding accuracy, no research exists on Aoralscan 3, as is the case for most new scanners. The technology is simply outpacing research. I have personally used the scanner

Figs. 3 & 4: The LED ring shows the scanning and connection status.

to fabricate crown and bridge restorations within my clinic with no accuracy problems.

The institute tests all scanners on the market and compares scans of the same tooth preparation using different scanners. We could not see a significant deviation in accuracy when comparing scans taken using Aoralscan 3 to those taken with other IOSs and even a laboratory scanner (using Geomagic Control software).

However, there is a clear difference in the detail of the rendered colour scan. The Aoralscan 3 scans are a little less detailed. It is not the worst colour scan rendering we have seen, but it is also not the highest quality (Figs. 7–10). None of this colour data is used in the manufacture of a crown though. The colour rendering is just a nice way to see the scan in a more realistic way and see the gingiva and margins rather than in a single colour.

The scanning image fabricated by the Aoralscan 3 software has a realistic but not lifelike appearance. The scans typically have quite high exposure, even when brightness calibration is carried out, and translucent areas (incisal edges) appear grey sometimes. After a refinement phase of the workflow, the scans are processed. After processing, some artefacts are taken care of by the software, and the final images look more realistic.

Overall Aoralscan 3 performs very well for various indications, including single crowns, implant scans, edentulous sites and deep preparations (Figs. 11 & 12). We tested full arches, quadrants, metals and edentulous areas, and it did a good job regardless. It also has a 22 mm scanning depth, which can be useful for scanning narrow or deep spaces.

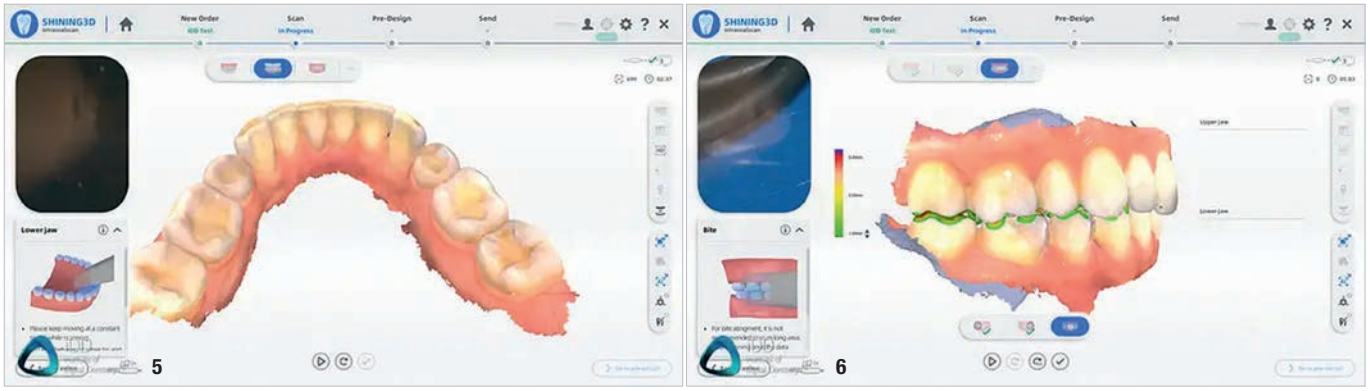
Using the scanner properly and controlling the scanning field correctly will result in a good scan. Poor usage will result in poor scans. Just like any other scanner, the operator is the key.

One nice workflow feature we liked was that, as soon as the user finishes the bite registration (which is very quickly aligned by the software), the scanner automatically shows a heat map of the occlusion without having to click on a menu. This is very useful and is a great workflow improvement over other IOSs.

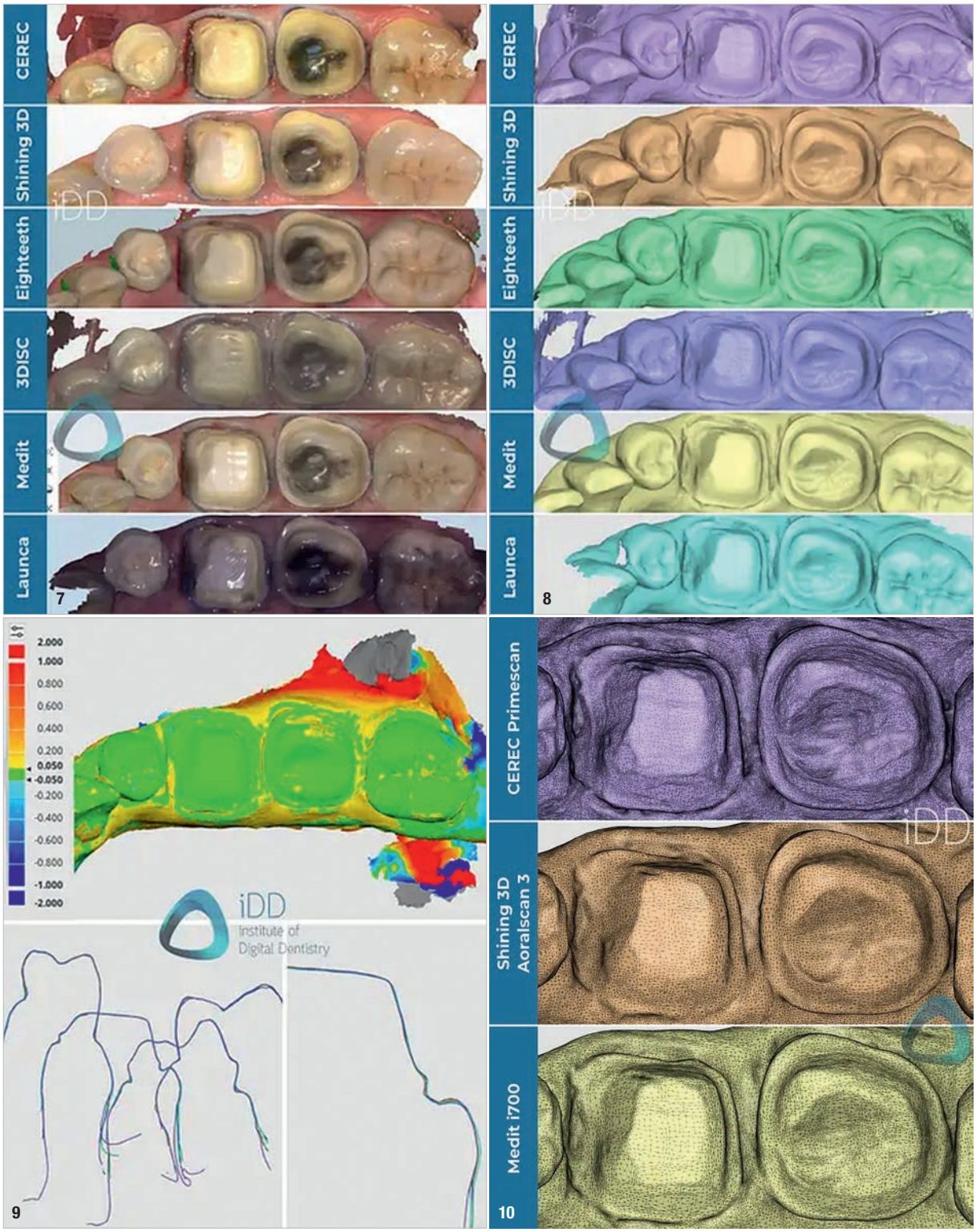
Software

The software that runs Aoralscan 3 is called Dental Launcher. The program is installed by running the app on the USB flash drive with the scanner.

The Aoralscan 3 software is easily the best out of all Chinese scanners tested by the institute so far. Frankly, it is better than many scanners on the market. It is very impressive for an affordable IOS.

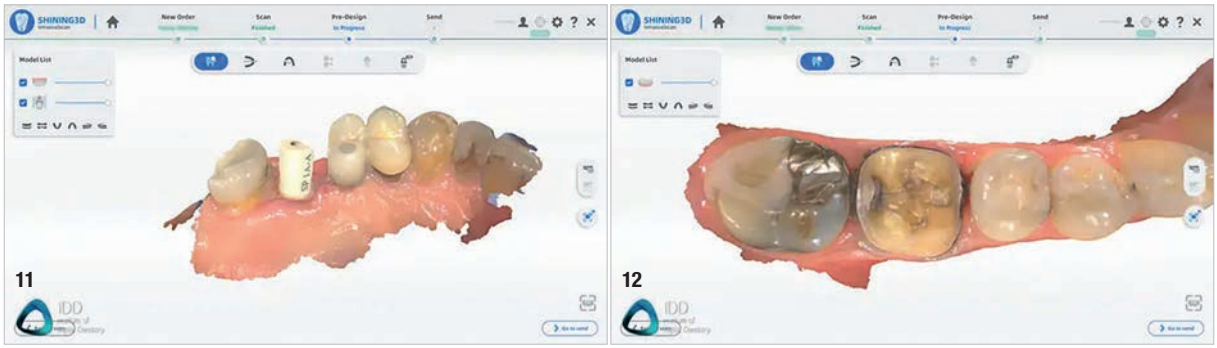


Figs. 5 & 6: Examples of scans taken with Aoralscan 3.



Figs. 7–9: The same preparations were scanned on the same day with six different scanners. **Fig. 10:** Tessellated mesh with all the vertices of the scans compared. The CEREC Primescan and Medit i700 scans show detail in greater complexity, contributing to a better-rendered result in the colour scan.

The software is modern-looking, easy to use, simplified and aesthetic and has many excellent features. The software is intuitive and efficient. It offers essential scanner software functions, such as analysing occlusion or reduction space, editing scans and removing any scanning data. It also has extra features not commonly seen in other low-cost scanners, like undercut analysis, margin placement, scanning coordinate adjustment and direct exocad export (Figs. 13 & 14). All these features work well and are highly polished for the most part.



Figs. 11 & 12: Aoralscan 3 handles arches, edentulous sites and metals well.

SHINING 3D provides fully fledged cloud-based storage for scans. The user can send cases to anyone with an Aoralscan 3 cloud account. Everything is stored locally, and it is up to the user to move it to the cloud manually.

Furthermore, this is the only Chinese scanner that has incorporated multiple scanner apps into the software—a model builder, orthodontic simulator and oral health report—a unique innovation. No other low-cost scanner has this line-up of apps.

Orthodontic simulation

As many already know, orthodontic simulators create an orthodontic alignment animation after the user has taken full-arch scans. Orthodontic simulation is a fantastic addition to the SHINING 3D software. I am surprised that such a low-cost scanner has this app, as most do not. In fact, most scanners double or triple the cost of Aoralscan 3. The Carestream Dental, Medit, TRIOS and iTero scanners have such simulators.

Typically these simulators can be a little hit and miss, but the SHINING 3D version seems to do well. This version is like the Medit ortho simulator but easier to use, requiring just a few clicks and making the entire workflow intuitive. It does have fewer features, however.

The Aoralscan 3 ortho simulator is fantastic for what it is. It is a communication tool that works very well and is highly automated, providing accurate automatic tooth segmentation, which was done close to perfect every time we tested it (Figs. 16 & 17). I was most impressed by the tooth set-up carried out automatically as the AI aligned the teeth. The orthodontic simulator even picks up missing teeth correctly, and any refinements needed are done easily.

The orthodontic simulator is interactive, but it does not have fully fledged modification tools, because it is intended as a communication tool. The simulations look great and are a powerful motivation tool for patients interested in orthodontic treatment, including aligners—a great addition to the software.

Model builder

The Aoralscan 3 model builder app, which is called AccuDesign, is another excellent addition to the software (Figs. 18 & 19). It allows the user to quickly and easily design printable 3D models from the scans within a few clicks—fitting for a company that also sells 3D printers. These model files can be created from any scan and are ready for printing. This software is not unique to Aoralscan 3, as a model builder app comes with many scanners, such as Medit i700, iTero, TRIOS and those of Carestream Dental, but Aoralscan 3 is significantly more affordable than those scanners.

This model builder software is easy to use. Within two to three clicks, the user can have a perfectly printable model.

Figs. 13 & 14: A number of tools are included, such as undercut analysis and margin tools.

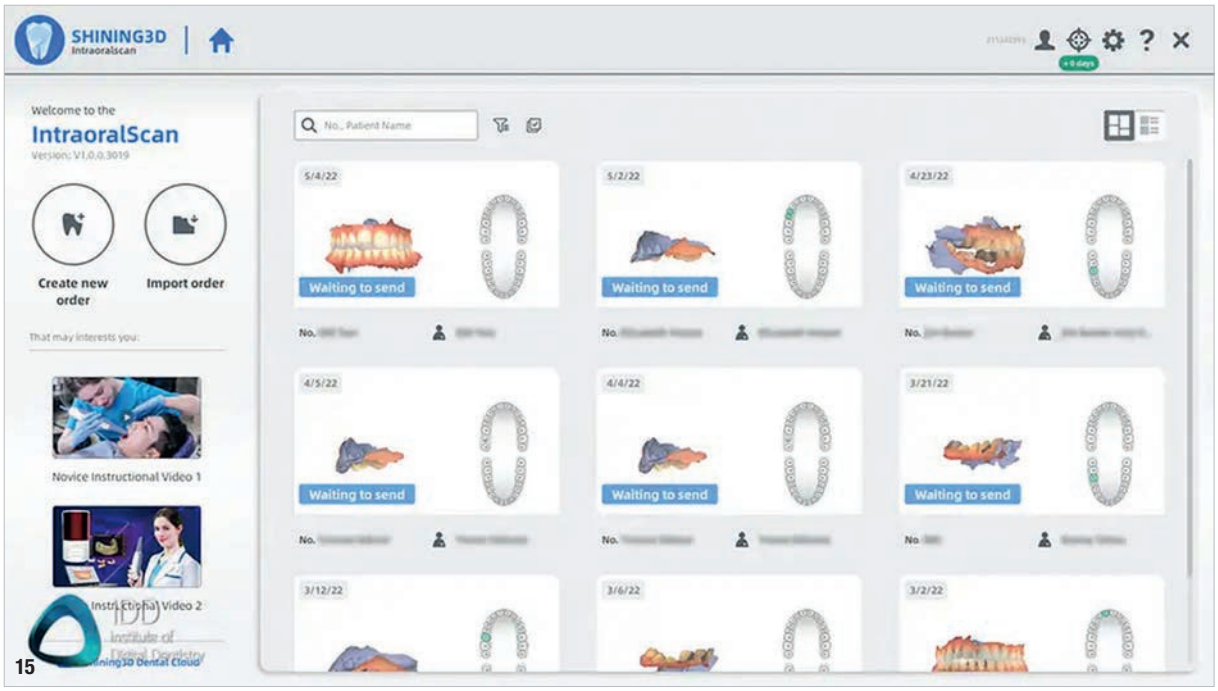
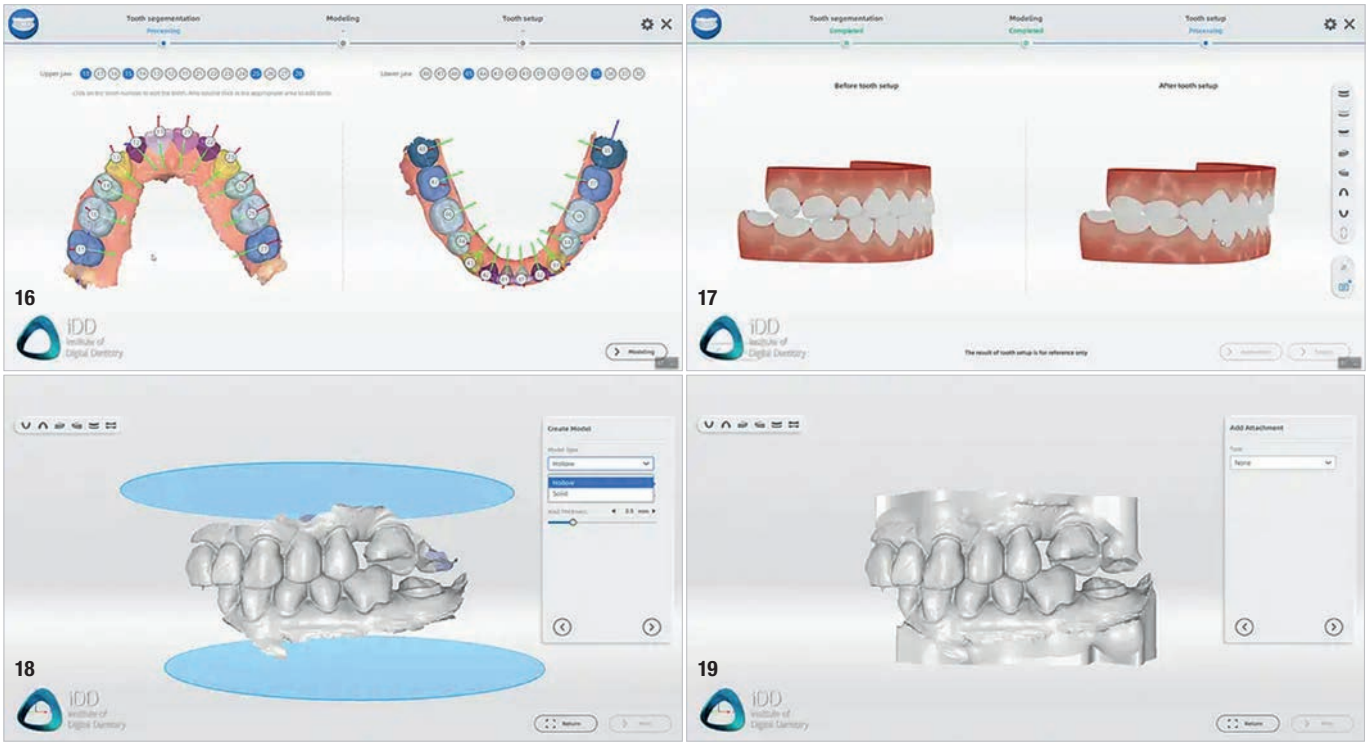


Fig. 15: Cases are presented in a unique and intuitive way.

Typically, users have to employ other software, such as Meshmixer, to achieve this. With Aoralscan 3, it is all done within the software, within a few clicks.

SHINING 3D seems to have taken some inspiration from Medit, as it has developed software with the same strengths. The model building process is streamlined and provides several options for the bases. The user can easily choose the thickness and height and whether the model should be hollow or solid or have draining holes or not and add text, among other options.

Chinese scanners have caught up on scanning speed, but most do not compete on software. This is changing. The SHINING 3D software is missing only a smile design



Figs. 16 & 17: Ortho simulation using Aoralscan 3 is automated and efficient. **Figs. 18 & 19:** The AccuDesign model builder looks rudimentary but works well.

component. It is impressive to see these software apps done so well in a low-cost Chinese IOS.

Ease of use

As with almost every scanner on the market these days, the Aoralscan software does very well at making the workflow straightforward. Ease of use comes from the software that supports the hardware. Overall the software has a level of polish not typically seen in Chinese scanners and is well thought out.

Everything works very well, from creating cases and sending them to the multiple scanner apps. When using the scanner daily, the workflow is intuitive (Fig. 20). It follows a simple step-by-step progression that is identical for almost every scanner on the market. Anyone familiar with typical intra-oral scanning strategies will be able to use this scanner.

The software also presents several on-screen tips during the workflow to help the user learn to scan and perform the workflow correctly (Fig. 21). Overall, it is an excellent scanning experience, especially for beginners.

Open or closed architecture

Aoralscan 3 is an open-architecture scanner, and the software enables easy export of scans in different formats, including STL, PLY, OBJ and exocad file types. The user will primarily use STL, the most widely accepted scanning format across laboratories and software. One key distinction is that the STL file is not a colour file. Although the scanner scans in colour, the user designs on a monochrome model when exporting in STL and opening in design software.

PLY and OBJ files include colour details, and it is great to see these being offered as an export option. The software makes exporting scans straightforward from both the software and the cloud. Exporting of scans in different file types is done automatically once the case has been completed (Fig. 22). This is stored locally with several additional files.

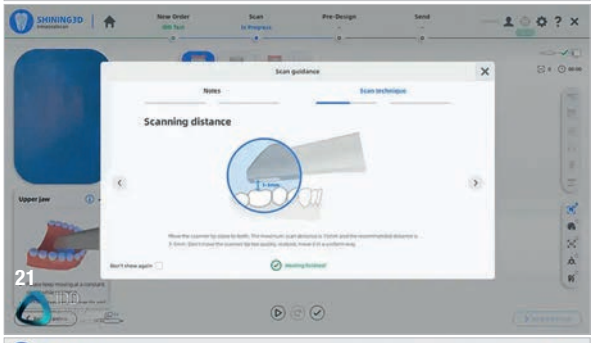
Price

Aoralscan 3 is one of the most affordable scanners. Its recommended retail price is US$10,999, but may vary slightly according to local tax policies and other factors. Prospective buyers are thus advised to check with their local distributor or reseller.

An ongoing cost to be considered is that of the scanning heads. Aoralscan 3 has removable and autoclavable scanning heads, providing ideal cross-infection control. This feature has become the norm across the IOS market. The autoclavable scanning heads have a limit of 100 autoclave cycles at 134 °C, after which they will need to be replaced.

In summary, although Aoralscan 3 is an entry-level scanner, it is very impressive. The scanner as a whole has good production quality. It does not feel like a cheap product and is impressive for the cost. It is a very well-performing scanner with great software for under US$11,000.

For the full review, please visit https://instituteofdigitaldentistry.com/ios-reviews/aoralscan-3-scanner-review-the-latest-ios-by-shining-3d.



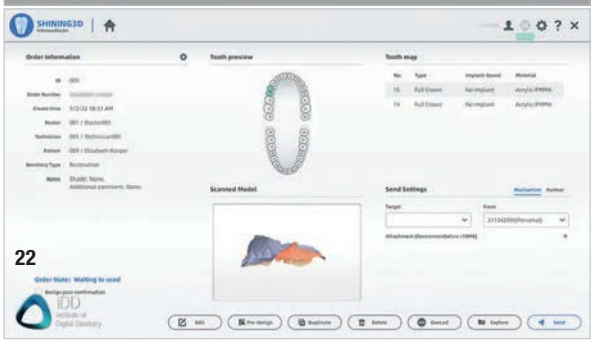


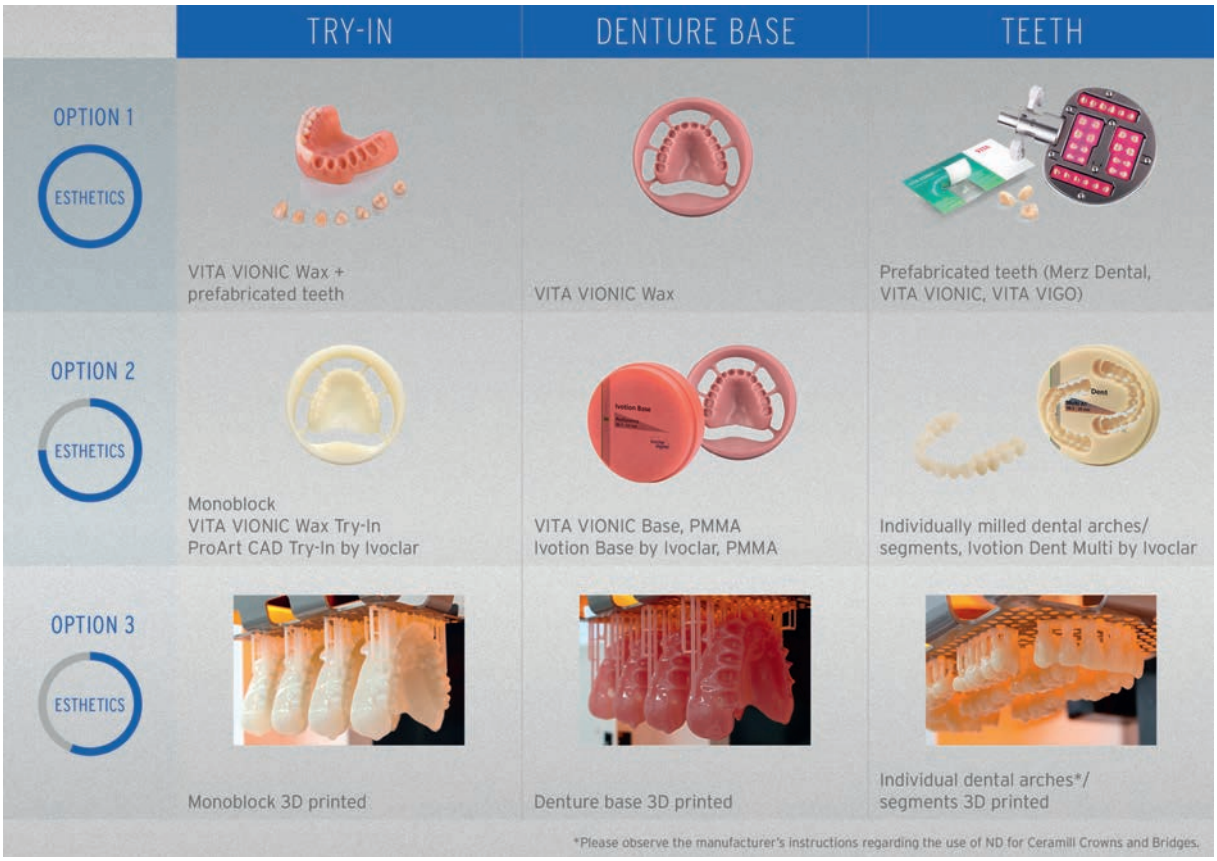
Fig. 20: The software is easy to use and has clear and intuitive buttons. **Fig. 21:** Scanning tips and tricks pop up throughout the workflow. **Fig. 22:** Exporting is simple and easy to do after scanning.

about

Dr Ahmad al-Hassiny is a global leader in digital dentistry and intra-oral scanners, carrying out lectures as a key opinion leader for many companies and industry. He is one of the few in the world who owns and has tested all mainstream scanners and CAD/CAM systems in his clinic. Dr al-Hassiny is also the director of the Institute of Digital Dentistry, a world-leading digital dentistry education provider with a mission to ensure dentists globally have easy and affordable access to the best digital dentistry training possible.

New materials for greater aesthetics and cost-efficiency

Ceramill FDS now offers option of milling dental arches and tooth segments



Amann Girrbach has expanded its Ceramill Full Denture System (FDS) to include the validated Ivotion materials from Ivoclar and has updated the Ceramill Mind software accordingly. This allows even more components to be individually combined in the fabrication of removable complete dentures. Users thus benefit from greater flexibility as well as time- and cost-efficiency.

The Ceramill FDS offers the industry's broadest range of options for fabricating dentures digitally. With the addition of the proven dental materials Ivotion Dent and Ivotion Dent Multi as well as the impact-resistant denture base material Ivotion Base, users can now also mill individual dental arches and tooth segments for the first time—all within a validated workflow. The pearl structure effect of Ivotion Dent Multi creates a particularly harmonious colour gradient. The previous options of milling denture bases or fabricating them via 3D-printing technology and combining them with prefabricated teeth from leading manufacturers have now been extended to include an aesthetic and cost-effective alternative.

In addition, the Ceramill FDS is distinguished by an end-to-end digital workflow and the seamless interaction of software and hardware. In this context, the Ceramill Mind software has been updated so that all components and materials and the stored gap dimensions and milling strategies are precisely matched.

"With the expansion of tooth libraries, fabrication possibilities and design options, the Ceramill FDS offers maximum flexibility. Thanks to the update, we are now in an even better position to cover different cost segments, so that individual patient wishes can be optimally addressed," said a delighted Maria Stroppe, product manager for laboratory CAD/CAM software and 3D printing at Amann Girrbach.

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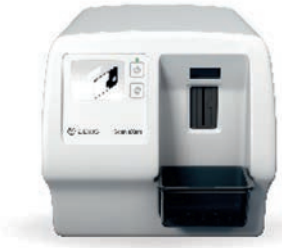

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