

Fields of application for the EOS technology in dentistry: dental prostheses (steps in production from left to right: with support structures, surface ready for veneer, after ceramic veneer) on a dental model and removable partial denture (right)

Additive Manufacturing in Dentistry

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Fig. 1: Dental bridge



Fig. 2: Dental model



Fig. 3: Removable partial denture

It doesn't matter whether you are producing crowns and bridges, plastic dental models or removable partial dentures, with EOS solutions you always get exceptional value for money. Laboratories and manufacturing services providers can thus work much more efficiently. The productivity of the EOS systems has a positive effect on the cost of parts and the quality of the final products is reliably high.

Digitisation of Dentistry



*Fig. 4:
In the dental laboratory: Digital technology
meets traditional craftsmanship*

Digital technologies have become established in several fields of dentistry and are already a firm part of the industry. Laser sintered dental prostheses have almost completely replaced precision casting in some countries. A further stage in the process has been digitised with the optical impressions, and more will follow. In future, more and more dental technicians will thus pick up a computer mouse instead of a wax knife and use an intraoral scanner instead of an impression tray – this saves time and makes work processes more efficient.

Established production technology for dental prostheses and models

Laser sintering is an Additive Manufacturing process to build up parts layer by layer and differs greatly from conventional manufacturing techniques. It uses 3D data on the oral situation of the patient as a basis; this is generated using intraoral scanners or by impression or model scans. The data set is processed directly with no loss of accuracy, such as is experienced with conventional impression methods, to produce the dental prosthesis or model and then 'sliced' into layers. The laser sintering system, which contains a bed of metal or plastic powder, generates the desired geometry layer by layer. A focussed laser beam then fuses the powder material on the basis of the digital data provided. Once one layer has been completed, the powder bed is lowered by a few hundredths of a millimetre and the process begins again.

The final product is characterised by a consistently high quality. It meets the needs of precision and aesthetics and satisfies budgetary/financial requirements. The manufacturing process has been sufficiently documented. In addition, software-supported work processes help reduce throughput times and the dental technician can concentrate on the key process stages of value creation such as the aesthetic and functional ceramic veneer.

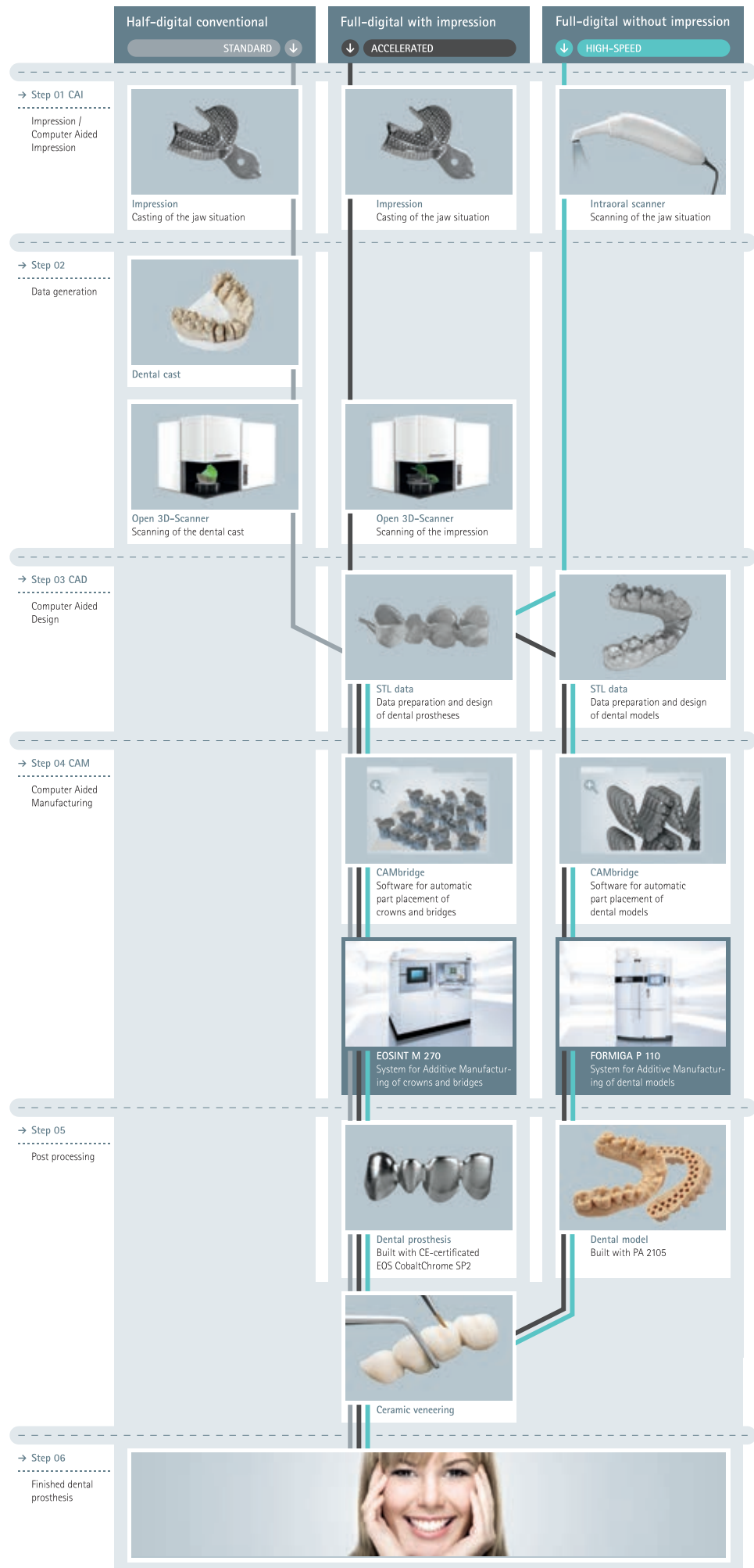
EOS GmbH has established a safe and strong position for its customers in the laser sintering of dental prostheses by acquiring a worldwide licence for patents from the firm of BEGO, a pioneer in the digital production of dental products.

Open process

The EOS process chain offers great flexibility since it has open system interfaces. The user can select the module of his or her choice and exchange data with this. The EOS systems work with STL data (STL = Surface Tessellation Language, a standard file format for 3D data) so that the dental technician can use a wide variety of computer-assisted design programs (e.g. from 3Shape, Dental Wings, Exocad).

Thanks to the independent system structure, the digital CAD/CAM process in design and data processing can be adapted to the economic, indication-specific and dental technology requirements of practices or laboratories so as to achieve an optimum production process.

From Data Generation to Digital Production



The Digital Manufacturing of Crowns and Bridges



Fig. 5:
Productive: A building platform can be charged with up to 450 units

Established production technology for medical products

Direct Metal Laser Sintering (DMLS) has been available to produce crowns and bridges since 2005. With over 60 installed systems worldwide, it is the most widespread solution on the market. Around 6.8 million units are currently being produced with these machines every year. Proof enough that the hardware and process have established themselves in dental technology.

The CE-certified material EOS CobaltChrome SP2 (CE 0537) and the EOSINT M 270 system are used for the digital production of crowns and bridges. Both elements of the process chain come

from EOS and satisfy the high quality standards for medical products. The finished products comply with the relevant standards EN 1641 as well as EN ISO 22674.

Fast and economical production of top-quality dental prostheses

The EOS systems work with an accuracy of $\pm 20 \mu\text{m}$ and can produce around 450 units at low cost within 24 hrs. This corresponds to an average construction time of around 3 mins per unit. The digitally produced dental prosthesis is of a constantly high quality. Following the construction process, the dental prosthesis only has to be separated from the platform and fin-

ished. The composite strength of the ceramic veneer is outstanding compared to other manufacturing techniques.

Hardly any personnel are needed to operate the DMLS system. This means that two production cycles can be run per day depending on the daily number of units and capacity utilisation and up to 80,000 units can be produced each year. People are only needed to set up and unload the system. The Additive Manufacturing of dental prostheses is an industrial production process and, thanks to the high productivity of the system, the production costs fall whilst the quality of the final products remains consistently high.

Further advantages at a glance

- Cheaper than precision casting and milling techniques
- Homogeneous metallic structure, high precision, good fit, constant quality
- Consistent tolerances, reproducible product properties
- Exact margin fit, good milling properties (in particular of primary crowns), flexible choice of veneer ceramics
- Production parameters are documented and the production of parts is monitored

The Digital Manufacturing of Dental Models

Economical process with a high production capacity

The FORMIGA P 110 and the material PA 2105 are used to produce dental models. 40 to 70 complete jaw models can be manufactured within 14 hrs (excl. cooling time) depending on the design and size. The high production capacity is a result of the multiple layer design. Not only are the individual parts connected by support elements, they are only fixed by the surrounding, non-fused powder. On account of the support-free method of production, no manual finishing is necessary, apart from a brief blasting.

The technology achieves applicable accuracies of up to $\pm 20 \mu\text{m}$ for a stump segment and $\pm 50\text{-}100 \mu\text{m}$ for whole jaw models depending on the geometry and design of the model. The dental models are of a sufficient quality to be integrated in an innovative and economical manufacturing chain. Thanks to the mechanical mode of production, the component precision, fit, feel and look are exactly reproducible.

The dental model is ideally produced parallel to the corresponding crown or bridge. Through the time-efficient production method the manufacturing time can be reduced on average by one working day and the dispatch times for conventional impressions can be eliminated fully from the manufacturing chain.

Design and use of the physical model

The user of the EOS technology has absolute flexibility of design, within the scope of dimensional accuracy requirements: the dental models can be manufactured as solid or hollow bodies and the common saw-cut model can also be produced. The models can be integrated in numerous articular systems as well as model base systems (e.g. from Baumann Dental, Model Tray). They are opaque, match the colour of the very popular super-hard plaster and their surface is slightly rough. The properties are therefore comparable to those of the classic master model. What's more, the plastic models are very hard-wearing, an important requirement if the crowns and tooth stumps have to be fitted and removed several times.

The plastic model is primarily used for ceramic veneers, to check for occlusions and to adjust the interproximal contact points. The fit of the crown margin is ensured by the CAD/CAM procedures and should only undergo a visual check. Anatomic impressions for analysis, on the



Fig. 6: Design variety thanks to digital production: Complete jaw model in form of a solid piece to check for occlusions, saw-cut model with pinholes, model with removable stumps (left to right)

other hand, can be produced and, on account of the temperature resistance, the model is also suitable for the production of aligners.

Further advantages at a glance

- Unbreakable, unlike plaster
- Models can be copied/produced directly in multiple copies (e.g. as a control model)
- Models can be automatically generated with patient or customer names
- Colour contrast and opacity facilitate veneering
- Higher throughput of the system allows economical production

The Digital Manufacturing of Removable Partial Dentures



*Fig. 7:
Stages of production for a laser sintered removable partial denture: Dental prosthesis directly after manufacturing, with support structures removed and surface polished, after completion (left to right)*

Competitive edge thanks to time-saving construction method

If several teeth are missing in a set of teeth, a removable dental prosthesis is the cheapest solution for the patient. For the dental laboratory, on the other hand, the conventional manufacture of model cast prostheses means a lot of work. The preparation of the cast model and the wax modelling based on this often takes more than one hour and the complete casting procedure including finishing is laborious and time-consuming. The digital production method, on the other hand, saves a lot of time: the design for the removable partial denture is ready in around 15 mins with only a few mouse

clicks. Thanks to the flexibility of design of DMLS, the modelling software is not restricted by the manufacturing technique. High-strength, rigid and at the same time filigree geometries can be produced. Casting errors can be ruled out.

Precise and at the same time economical technology

The EOS system is very accurate and therefore makes laboratory work easier. The removable partial denture that is produced has an accuracy of $\pm 20 \mu\text{m}$ and is of a consistently high quality. But the method is at the same time economical too. Around 48 units can be produced within 24 hrs This corresponds to an average con-

struction time of around 30 mins per unit.

Certified process chain with a specially developed material

Removable partial dentures are made with the EOSINT M 270, which is already established on the market. The fine powder particles produce a fine-grain structure compared to that of the casting and the material characteristics are matched to the application. The removable partial dentures produced with the aid of computers have a higher strength than a conventional model cast and the risk of a clamp breakage is lower. The high level of detail supports the reproduction of pitted structures.

Both the material and the machine come from EOS and satisfy the high quality standards that apply for medical products. The finished products comply with the relevant standards EN 1641 as well as EN ISO 22674.

Fig. 8:

Digital manufacturing: The laser fuses the metal powder layer by layer with 200 W and a temperature of 1400 °C

Further advantages at a glance

- Production at low costs
- Density, elasticity, ultimate strain correspond to dental technology requirements
- Homogeneous metallic structure, high precision, good fit, constant quality
- Consistent tolerances, reproducible product properties
- Manufacturing parameters are documented and the production of parts is monitored



EOSINT M 270 – Certified Production of Dental Prostheses



Fig.9:
EOSINT M 270: System for Additive Manufacturing of crowns and bridges as well as removable partial dentures directly from electronic data

The system is established on the market and manufactures crowns and bridges as well as removable partial dentures by Direct Metal Laser Sintering (DMLS). The fibre laser in the EOSINT M 270 achieves accuracies of +/- 20 µm. Thanks to the controlled material fusion, the dental prosthesis that is produced is homogenous, of a constantly high quality and of a higher quality than cast parts.

The materials that can be processed, EOS CoCr SP2 and EOS CoCr RPD, are compatible and permit flexible changes on account of the material composition. Two optimised dental manufacturing processes can be run on just one system.

Technical data

Building volume (incl. building platform)	250 x 250 x 215 mm (9.85 x 9.85 x 8.5 in)
Layer thickness	20 µm (0.001 in)
Laser type	Yb-fibre laser, 200 W
Precision optics	F-Theta lens, high-speed scanner
Scan speed	Up to 7.0 m/s (23 ft/sec)
Power supply	32 A
Power consumption	Maximum 8.5 kW/typical 2.4 kW (incl. cooler)
Nitrogen generator	Integrated
Compressed air supply	7,000 hPa; 20 m ³ /h (102 psi; 26.2 yd ³ /h)

Dimensions (W x D x H)

System	2,000 x 1,050 x 1,940 mm (78.8 x 41.4 x 76.4 in)
Recommended installation space	Approx. 3.5 x 3.6 x 2.5 m (137.9 x 141.8 x 100 in)
Weight	Approx. 1,130 kg (2,491 lb)

Data preparation

Software	EOS RP Tools, CAMbridge
CAD interface	STL, DCM (3Shape)
Network	Ethernet
Certification	CE

FORMIGA P 110 – Economical Production of Dental Models



*Fig.10:
FORMIGA P 110: System for the
Additive Manufacturing of dental
models directly from electronic data*

The system produces a number of different dental models in only a few hours with an overall building volume of 200 x 250 x 330 mm and in several consecutive layers. The productivity of the system has a positive effect on the costs per part and the quality of the final products is reliably high. Thanks to its efficiency and flexibility, the FORMIGA P 110 can be ideally integrated into the workflows of a dental laboratory. All of this for a relatively low investment cost.

A more detailed description can be found in the FORMIGA P 110 system brochure.

Technical data

Building volume (incl. building platform)	200 x 250 x 330 mm (7.9 x 9.8 x 13 in) Excl. pyrometer measurement spot
Building speed (depending on material)	Up to 20 mm height/h (0.79 in/h)
Layer thickness (depending on material)	0.06 mm, 0.1 mm, 0.12 mm (0.0024 in, 0.0039 in, 0.0047 in)
Laser type	CO ₂ , 30 W
Precision optics	F-Theta lens
Scan speed	Up to 5.0 m/s (16.4 ft/sec)
Power supply	16 A
Power consumption	2 kW
Nitrogen generator incl. external nitrogen connection	Integrated
Compressed air supply	Minimum 6,000 hPa; 10 m ³ /h (87 psi; 13.08 yd ³ /h)

Dimensions (W x D x H)

System incl. powder containers and touch screen	1,320 x 1,067 x 2,204 mm (51.97 x 42.01 x 86.77 in)
Recommended installation space	Approx. 3.2 x 3.5 x 3.0 m (126 x 137.8 x 118.1 in)
Weight	Approx. 600 kg (1,323 lb)
Unpacking and sieving station (optional)	1,200 x 700 x 1,500 mm (47.24 x 27.56 x 59.06 in)
Powder mixing station (optional)	700 x 500 x 1,000 mm (27.56 x 19.69 x 39.37 in)

Data preparation

Software	EOS RP Tools (optional), Desktop PSW
CAD interface	STL (optional: converter to all common formats)
Network	Ethernet



Fig.11:
Polished bridge made from
EOS CobaltChrome SP2

EOS CobaltChrome SP2: certified material for crowns and bridges for the EOS system EOSINT M 270.

A special cobalt-chrome-molybdenum-based super-alloy is used to manufacture crowns and bridges. It is biocompatible, certified for use in the dental industry (CE 0537) and very inexpensive compared to precious metal alloys. According to EN ISO 9693, the Schwickerath adhesive strength is 42 MPa if the recommended VITA VM 13 ceramic is used.

Material composition	Material properties	
Co: 63.8 wt %	Relative density	Approx. 100 %
Cr: 24.7 wt %	Density	8.5 g/cm ³
Mo: 5.1 wt %	Proof strenght (Rp 0.2 %)	850 MPa
W: 5.4 wt %	Ultimate tensile strength	1350 MPa
Si: 1.0 wt %	Percent elongation	3 %
Fe: max. 0.50 wt %	Young's Modulus	Approx. 200 GPa
Mn: max. 0.10 wt %	Vickers hardness HV10	420 HV
Free from Ni, Be and Cd acc. to EN ISO 22674	Coefficient of thermal expansion (25 - 500 °C)	14,3 x 10E-6 m/m°C
	Coefficient thermal expansion (20 - 600 °C)	14,5 x 10E-6 m/m°C
	Melting interval	1410-1450 °C

Material properties after stress-relieving (1 h at 750 °C), oxid fire simulation (5 mins at 950 °C) and ceramic fire simulation (4 x 2 mins at 930 °C) acc. to EN ISO 22674. Detailed information can be found in the material data sheet and the instructions for use.

EOS CobaltChrome RPD: bio-compatible material for removable partial dentures for the EOS system EOSINT M 270.

The cobalt-chrome-molybdenum-based super-alloy is used for the manufacture of removable dental prostheses. The material composition is identical to that of the CE-certified EOS CobaltChrome SP2 (CE 0537). The material is free from Ni, Be and Cd and its mechanical properties satisfy the requirements of the standard EN ISO 22674:2006 Type 5.

When it comes to accuracy and fit, the material is comparable to traditional model cast alloys of cobalt chrome. The design guidelines are also similar. Data processing is carried out with the customised software functions of the new CAMbridge 2012 RPD module from 3Shape.

PA 2105: coloured plastic material for dental models for the EOS system FORMIGA P 110.

The pigment-filled polyamide-12-powder has a colour similar to that of plaster. The familiar colour contrast to dental restoration and the high mechanical and thermal resistance permit an optimum check of the fit as well as veneering of the dental prosthesis.



Fig.12: Removable partial denture with support structures made from EOS CobaltChrome RPD



Fig.13: Dental model made from PA 2105 in the form of a solid complete jaw model to check for occlusions

EOS systems are able to manufacture medical devices. However, EOS cannot offer any guarantee that these devices meet all requirements

From Users Come References: Statements from our Customers and Partners



The BEGO Bremer Goldschlägerei Wilhelm Herbst GmbH & Co. KG is one of the leading international dental companies. The owner-led company provides a wide selection of products and services "Made in Germany" through their divisions BEGO Dental, BEGO Medical, and BEGO Implant Systems.

Christoph Weiss, Managing Director of the BEGO group: "The long R&D activities of BEGO in the field of lasersintering finally pay out – the unbeatable advantages of the technology in the dental area are obvious. The company EOS with its comprehensive technology know-how uses our BEGO patents and is a very attractive cooperation partner."



Phibo® is a leading European multinational company in implantology, prosthesis in CAD-CAM and digital solutions and services. Phibo®, with operations also in Italy, Portugal, France, Germany, Colombia and Dubai has researched, developed, manufactured and sold dental solutions for more than 20 years with a strong research vocation and a high scientific component. The Company's goal is to be a worldwide reference in dentistry solutions.

Francesco Alsina, Chief Innovation Officer for Phibo®: "In the CAD-CAM field, EOS laser sintering technology has proved to be a relevant partner for Phibo®. Through our R&D in this field Phibo® has gained a differential positioning regarding solutions for complex implant restorations incorporating processes that complement the benefits of laser sintering. This approach has meant a significant leap for the dental sector increasing the volume of CAD/CAM prosthesis solutions while offering better options for dental clinics and their patients."



Heraeus Dental is a global supplier of dental products headquartered in Hanau, Germany, with subsidiaries in the US, Europe, and Asia.

Dr. Uwe Böhm, Head of R&D Prothetik at Heraeus Dental: "We have integrated laser melting into our CAD/CAM-system cara, because this technology now allows us to build dental frames in high quality. We offer our customers a flexible and efficient way to process base metal. In cooperation with EOS, Heraeus offers CAD/CAM users an up to date SLM technology, that enables tailored and homogenous crowns and bridges."



Innovative technology and strategic direction have led Fusion Dental Group to quickly become the world largest service provider of dental crowns and bridges. Founded in 2009 and operating production sites in Europe and USA, Fusion created a global dental network connecting dentists, dental labs and cooperative production centers. The company's next-generation products are made available via meticulous manufacturing and quality assurance process, based on the latest technologies and advanced information systems, all of which are supported by local expert teams.

Shai Waisel, Chairman of Fusion Dental Group: "With our 1 million dental unit scheduled for production during 2013, we continue to commit supplying our customers with the highest quality products in less than 48 hours and with a lifetime warranty. Since our focus is on the best quality, we decided on EOS. The company stands out through its unbeatable combination of German punctuality and professional yet cooperative approach."

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