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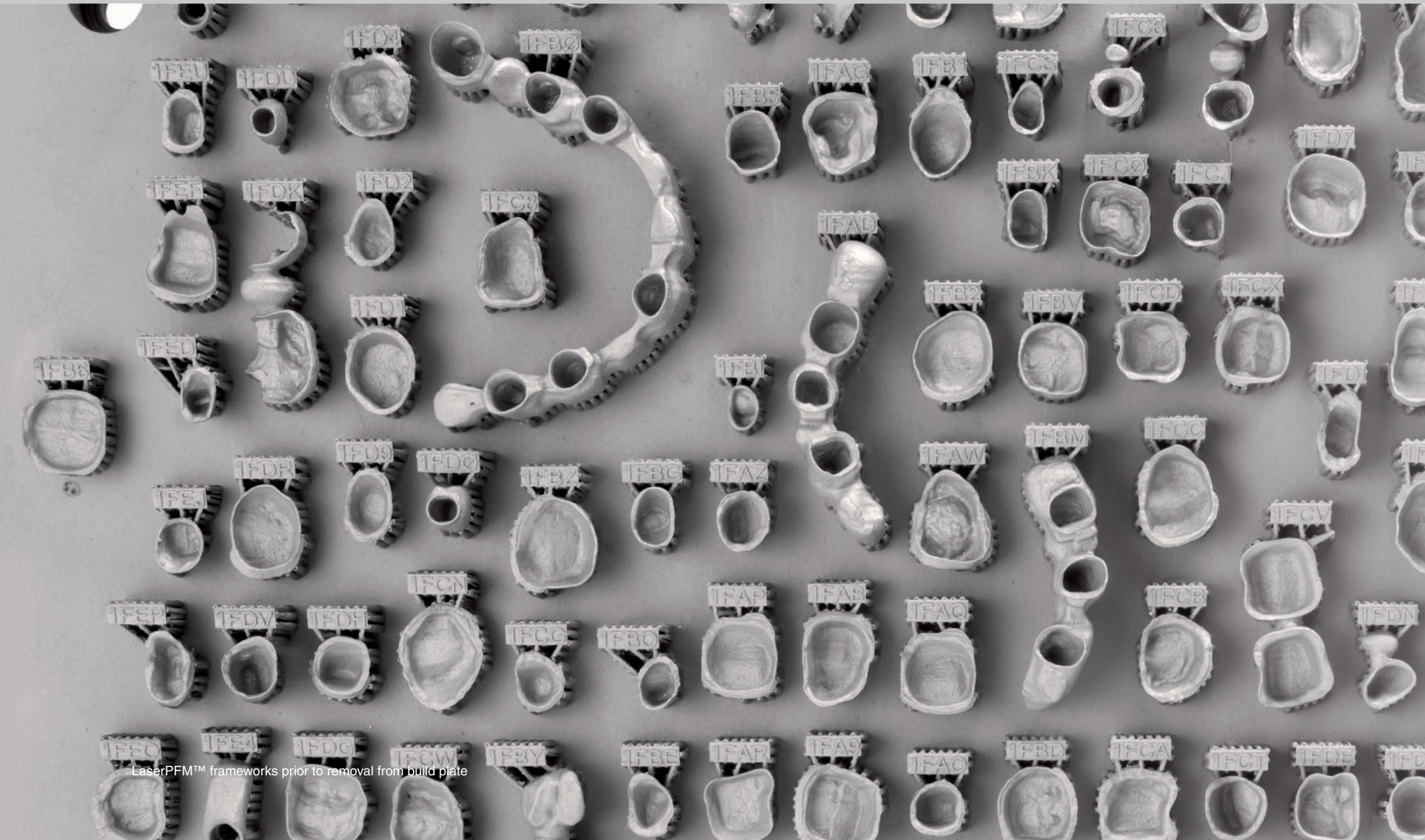
Additive manufacturing systems - 3D printing for healthcare



LaserPFM™ frameworks prior to removal from build plate

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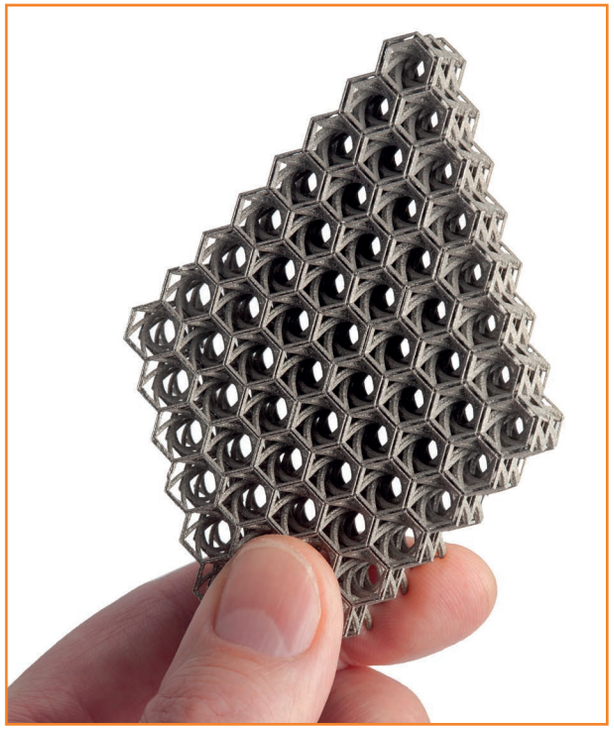
Additive manufacturing

Also known as...

- 3D printing
- Laser melting
- Additive layer manufacturing (ALM)
- Selective laser melting (SLM™)
- Direct metal laser sintering (DMLS™)
- Selective laser sintering (SLS)



The possibilities of additive manufacturing

Additive manufacturing (AM), also known as 3D printing is an exciting manufacturing technology whose benefits are being readily embraced with real life applications being developed daily.

AM removes many of the constraints seen in more traditional manufacturing methods such as milling, casting or fabrication. This opens up new possibilities for complex geometries and mass customisation of parts, at a commercially viable cost, that were previously unfeasible.

With the capability of producing complex features and accurate parts, AM is highly suited to the production of medical and dental devices in both cobalt chrome and titanium.

Custom medical device manufacture for craniofacial implants and guides, orthopaedics and dental devices are just some of the areas in which AM has been applied, with many more applications possible. Renishaw is keen to work with its customers to improve existing custom devices, or develop new applications that are yet to be exploited.

A regulated approach

Renishaw has been manufacturing dental devices for many years and has extensive experience in global healthcare regulation.

We have produced hundreds of thousands of devices under our ISO13485 quality system and we understand the need for regulatory compliance. To this end we can pass on our experience to our customers saving time and resources when setting up manufacturing systems.

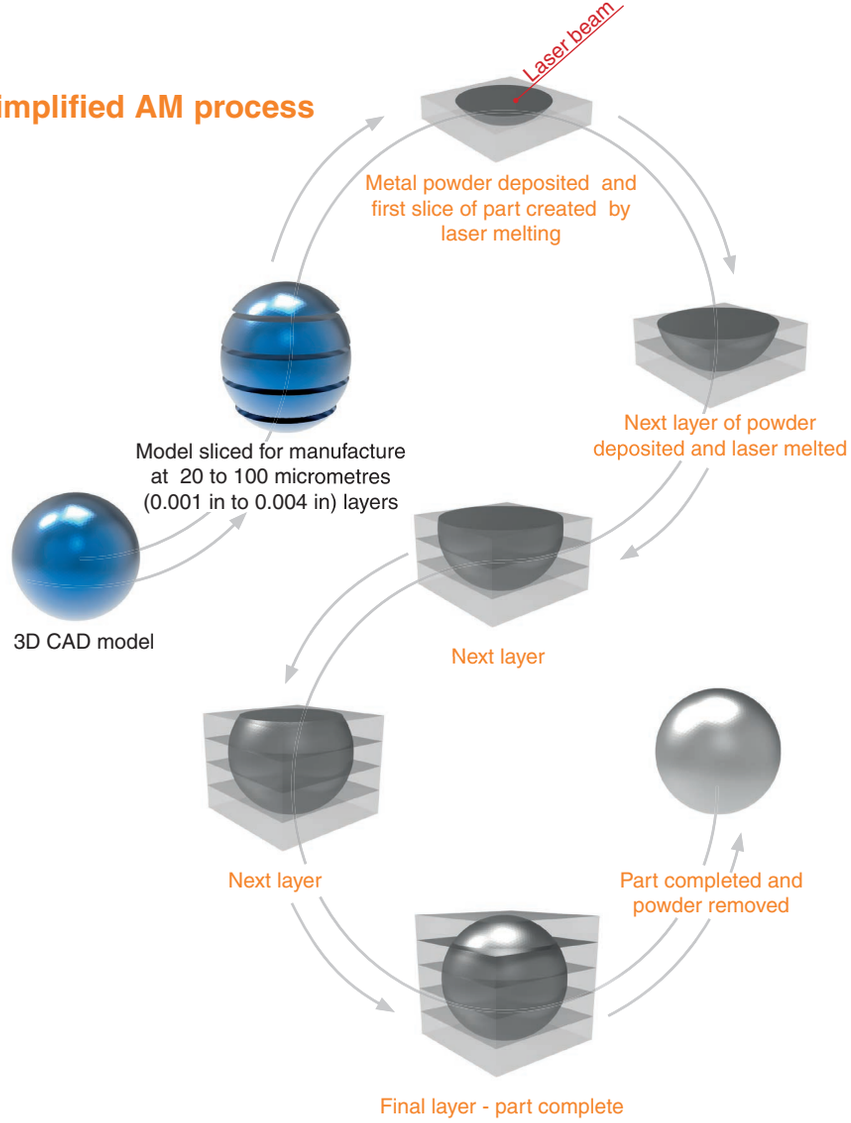
bsi. ISO 13485 Medical Devices Quality Management

How additive manufacturing works

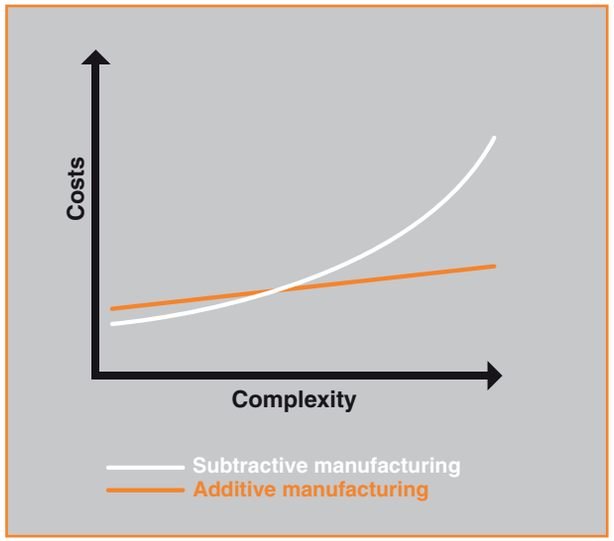
AM in brief

Renishaw's laser melting is a pioneering additive manufacturing process capable of producing fully dense metal parts direct from 3D CAD using a high-powered fibre laser. Parts are built from a range of fine metal powders that are fully melted in a tightly controlled atmosphere layer by layer in thicknesses ranging from 20 to 100 microns.

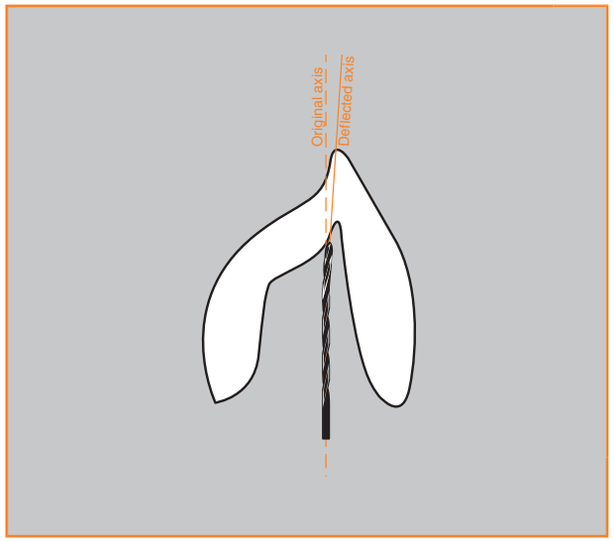
Simplified AM process



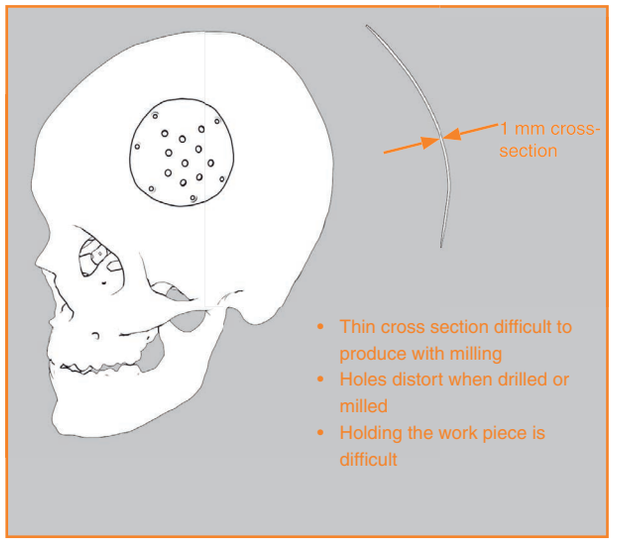
Why choose additive manufacturing for healthcare?



Subtractive manufacturing's (e.g. milling) cost increases with complexity



Use of small tooling for better access sacrifices tool stiffness and accuracy



Challenges when milling thin sections, particularly cranial plates

Additive manufacturing can give tangible benefits over traditional manufacturing techniques.

Medical and dental devices are inherently complex in their physical form and do not easily lend themselves to a traditional manufacturing process where higher volumes are required to make the process viable. In the case of medical or dental devices it is less a case of mass production as mass customisation.

Milling centres, performing traditional subtractive manufacturing, are still capable of mass manufacture and mass customisation however they are often less efficient when the components have complex and bespoke forms.

Milling removes unwanted material, in contrast additive manufacturing or 3D printing adds only the material required, resulting in a far more efficient use of material and a more predictable manufacturing cost. This gives manufacturers the opportunity to take advantage of higher efficiencies and a lower carbon energy consumption.

In addition to the cost of parts rising as the complexity increases there are also more constraints on part manufacture through subtractive manufacturing.

To reach small features, often critical to a successful clinical outcome, a milling machine would have to use very small diameter tooling. This increases cycle time, sacrifices tool stiffness and accuracy whilst also adding further uncertainty to the cost and durability of the tooling.

AM does not suffer from this major issue and is capable of producing highly detailed features. This gives the AM user a significant competitive advantage making it ideal for both medical and dental applications.

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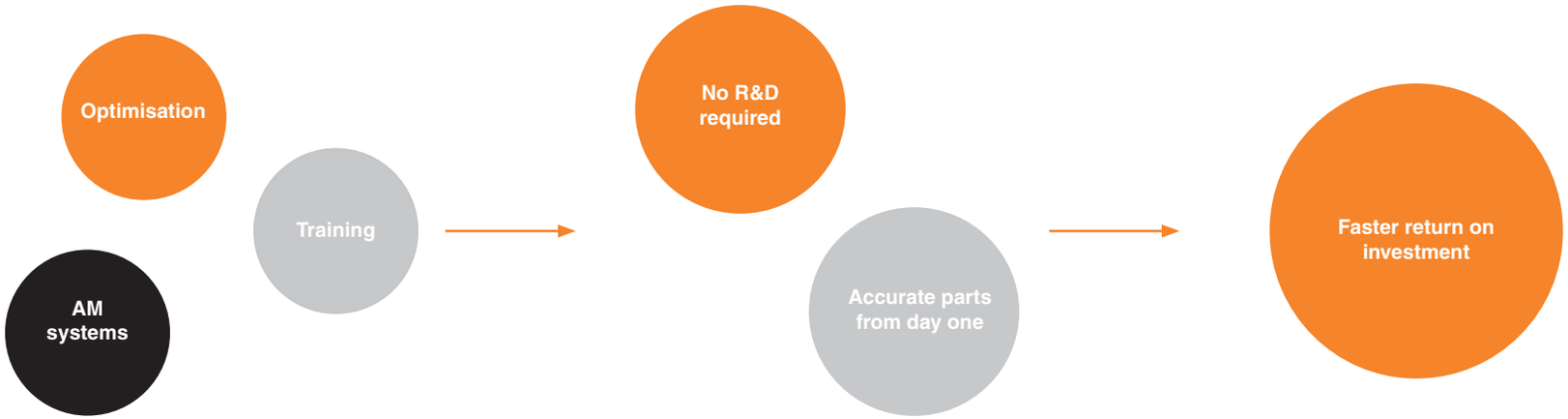
Optimisation enables faster returns



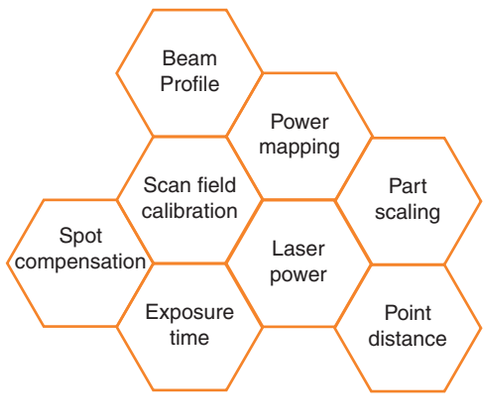
As with any investment the faster a machine can commence production, the faster the return on investment can begin. That is why all of Renishaw's dental and medical AM systems are individually optimised before final acceptance.

With a possible 140+ parameters to choose from, tuning a laser melting system requires a systematic approach. Renishaw has the experience and expertise and can deliver significant time savings on process optimisation and set up for our customers.

Why Renishaw's set-up is different

Through our history of working with a variety of suppliers of AM systems we have found that just as every milling machine is different, the same is true for AM systems. That is why our system set-up or "optimisation" is different. Renishaw has developed an efficient and effective process to ensure that your AM system is ready to use with the optimal settings for your machine and your application.

In addition we offer a comprehensive training schedule that not only covers machine operation but all of the peripheral activities that are also part of a sucessful implementation.



A selection of optimisation parameters

Manufacturing requires efficiency

The key to profitable manufacturing is an efficiently set up process. Conventional CNC milling machines need to at least know the tool dimensions relative to the raw material before they can mill a rough part. Improving the accuracies of these measurements will improve part accuracy. However these are not the only parameters that affect accuracy, finish and speed of manufacture. Understanding feedrate, tool speed, tool geometry, tool path optimisation, spring passes and coolant type, to name just a few parameters, can significantly improve the manufacturing process.

Additive manufacturing is no different. There are a multitude of options to enable fine tuning of the process which can take the quality of a part from good to excellent.

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Why Renishaw AM?

Renishaw's additive manufacturing systems are developed to deliver parts with an excellent surface finish, a high density structure and accurate dimensions. To ensure production is consistent, these are all delivered as part of a validated process.

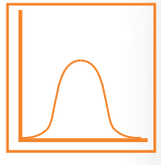
Density and surface finish

- Aim for density of 99.5% to 100%
- Surface finish critical to many applications
- Final part strength and ductility affected by density
- Fine tuning of point distance, exposure time, beam profile, power mapping, scan field calibration, part scaling, laser power and spot compensation are all included in optimisation for best density and surface finish

Accuracy

- An essential requirement of dental and medical parts
- Specialist error mapping achieves consistent accuracy across the build plate
- Renishaw delivers systems with accuracy capabilities, pre-agreed with the end user

Process validation



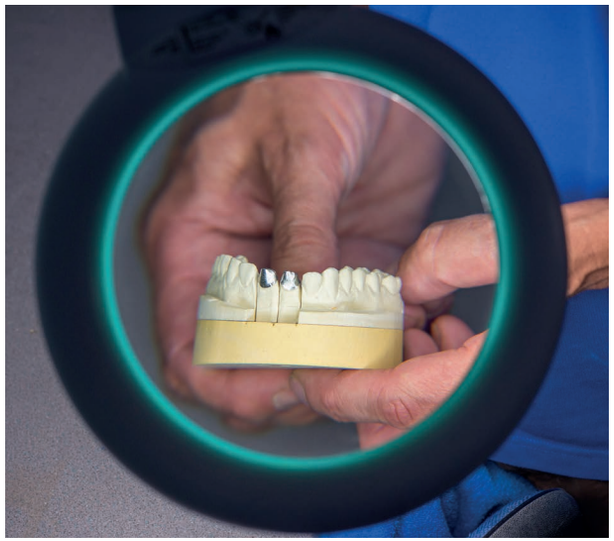
- Validating the machine enables consistent parts
- Allows predictable manufacturing performance
- Renishaw validates all dental and medical systems prior to final sign-off

Dental 3D printing in practice

CBC Dental Lab is a multi-award winning restorative laboratory, based near Bristol, UK. Dealing with a variety of cases from tooth-borne restorations to implant-supported smile makeovers. CBC has built a successful business over the last 30 years serving clients throughout the United Kingdom.

When Renishaw first introduced LaserPFM™, laser-melted cobalt chrome (CoCr) frameworks in 2010 CBC were quick to see the potential and introduce them into the lab. CBC was already familiar with the digital work-flow and the benefits that can be realised through its use of Renishaw's zirconia frameworks. By introducing these benefits to the metal side of the laboratory, CBC has been able to realise efficiency improvements by subcontracting metal framework manufacture to Renishaw, whilst using their valuable staff for more profitable activities in the lab.

However, a more important aspect to CBC is the consistent quality brought about by the frameworks and their fixed cost. This results in happier dentists, less remake work and unlike casting alloys, the price of laser sintered frameworks remains consistent. All these combine to allow CBC to better plan its business for the coming year.



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"After trying other technologies for metal frameworks, we settled on laser-melted frameworks which gave us superior results. We would now find it impossible to return to full manual casting. The quality and consistency have made a big difference to our business. When surveyed, our dentists gave 100% positive feedback on laser melted frameworks. They indicated they would be disappointed if we returned to old traditional techniques."

CBC Dental Lab (UK)

Additive manufacturing changing lives

Motorcycle trauma victim, Stephen Power has seen first hand the benefits of surgeons and engineers working together and how the outcome can change a person's life.

Having been involved in a horrific accident that left Stephen requiring reconstructive surgery, he was left with a number of facial disfigurements that changed his life.

However a consultant in cleft and maxillofacial surgery at the Morriston Hospital in Swansea, Mr Adrian Sugar, was Stephen's surgeon and was keen to push the boundaries of his profession and embrace new techniques and processes.

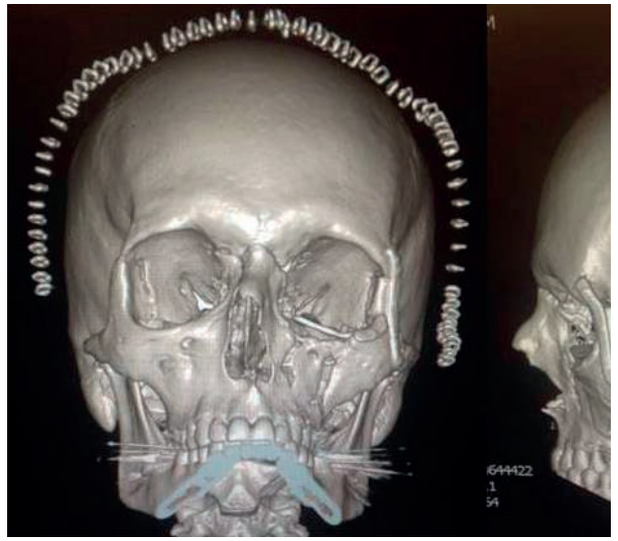
Maxillofacial implants have been used for a number of years and recently 3D printing has enabled a more bespoke solution. Despite this the surgical procedure itself is still time consuming and onerous. Soft tissue incisions and bone positioning can be a freehand process making the surgery more complex than perhaps it needs to be and with a less predictable outcome.

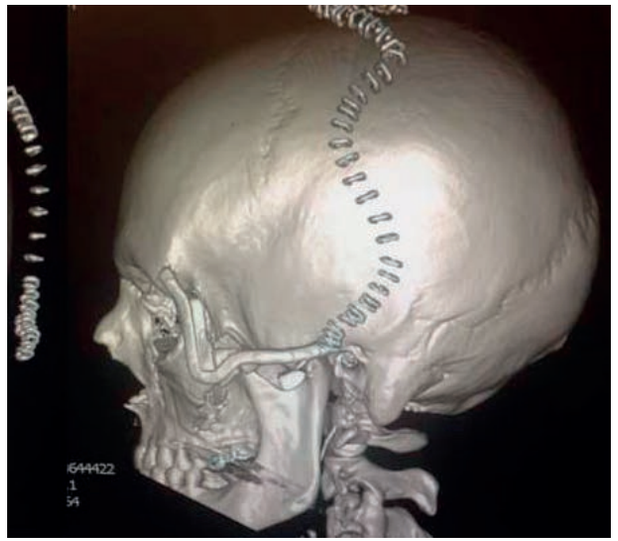
Engineers routinely use jigs and fixtures to ensure a high quality and repeatable outcome and this is exactly what Mr Sugar required for this case. By planning where he wished to make the bone incisions prior to the surgery, he could remove some of the guess work. Then, using a placement aid for the final implants Mt Sugar could ensure a near perfect fit and a much more efficient operation all round.

Renishaw worked in collaboration with the Centre for Applied Reconstructive Technologies in Surgery (CARTIS) in South Wales, to provide Mr Sugar with the bone cutting jig and implant placement guide that made the surgery easier

"I think it's incomparable - the results are in a different league from anything we've done before" - Mr Adrian Sugar.

Stephen's response was even more emphatic: "It is totally life-changing".





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> I think it's incomparable - the results are in a different leaguefrom anything we've done before.
>
> **Mr Adrian Sugar,**
> **Consultant Cleft and Maxillofacial Surgeon**

Stephen Power after reconstructive surgery performed by Mr Adrian Sugar

Healthcare products by Renishaw

Our technologies are also helping within applications such as dentistry, neurosurgery, chemical analysis and nanotechnology research. These include systems, materials and manufacturing services that allow dental laboratories to manufacture high-quality dental restorations and engineering solutions for stereotactic neurosurgery. We also supply non-destructive analytical tools that identify and characterise the chemistry and structure of materials.

Dental scanners

3D contact scanners and non-contact optical scanners used for digitising of dental preparations and for the measurement of implant locations for tooth-supported frameworks, custom abutments and implant bridge structures.

Neurosurgical planning software

Planning software that allows advanced planning of targets and trajectories for stereotactic neurosurgery.

Neurosurgical robot

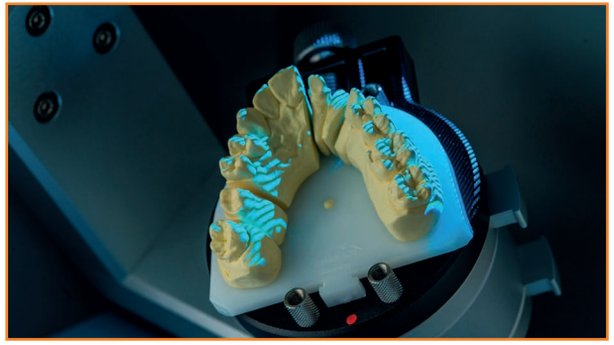
A stereotactic robot that provides a platform solution for a broad range of functional neurosurgical procedures including deep brain stimulation (“DBS”), stereoelectroencephalography (“SEEG”), neuroendoscopy and stereotactic biopsies.

Neurosurgical Implants

Implantable devices that allow surgeons to verify expected DBS electrode position relative to targeted anatomy using magnetic resonance imaging (“MRI”) for the treatment of Parkinson’s disease, other movement disorders and neuropathic pain.

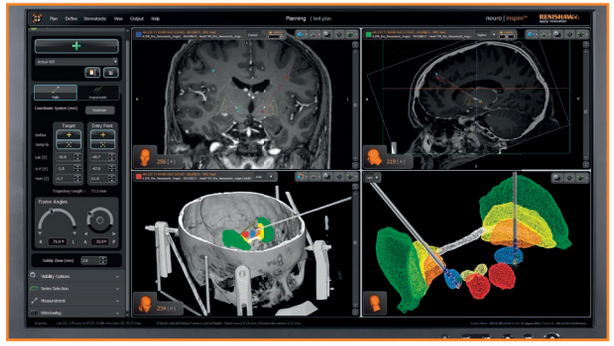
Raman microscopes

Scientists and engineers worldwide use Renishaw’s research-grade inVia Raman microscopes for the non-destructive chemical analysis and imaging of materials. Its high-speed, high-quality results and upgradeability are valued in fields as diverse as nanotechnology, biology and pharmaceuticals.



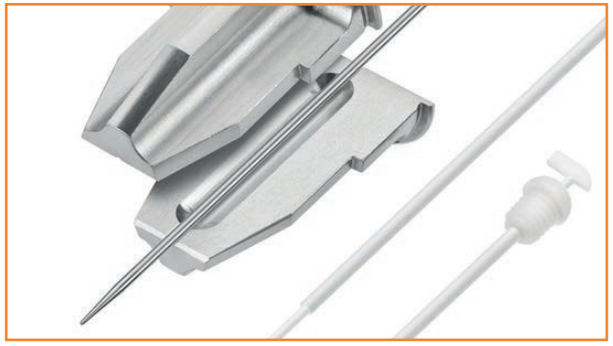
Dental scanners

Neurosurgical robot



Neurosurgical planning software

Raman microscope



Neurosurgical implants

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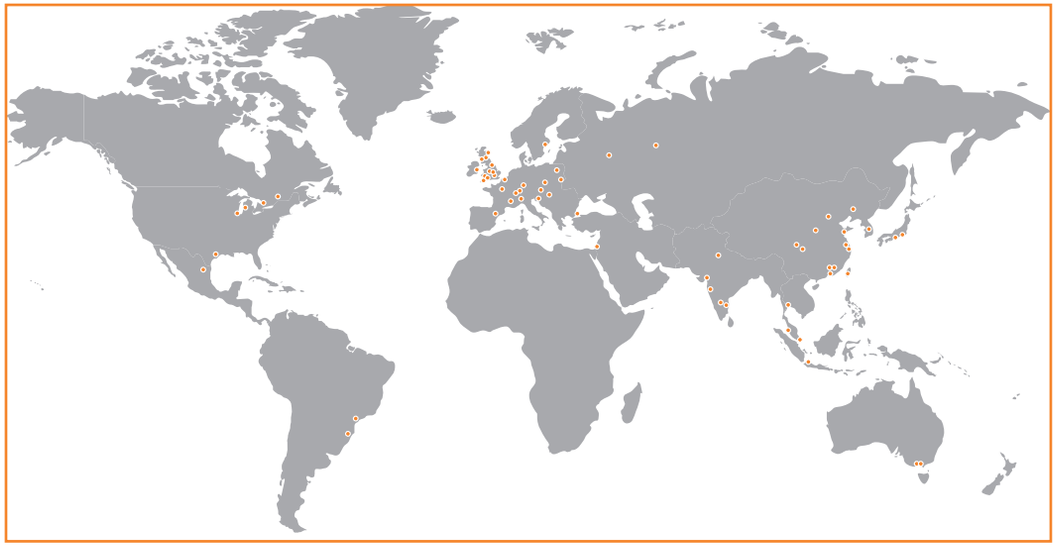
About Renishaw

Renishaw is an established world leader in engineering technologies, with a strong history of innovation in product development and manufacturing. Since its formation in 1973, the company has supplied leading-edge products that increase process productivity, improve product quality and deliver cost-effective automation solutions.

A worldwide network of subsidiary companies and distributors provides exceptional service and support for its customers.

Products include:

- Additive manufacturing and vacuum casting technologies for design, prototyping, and production applications
- Dental CAD/CAM scanning systems and supply of dental structures
- Encoder systems for high accuracy linear, angle and rotary position feedback
- Fixturing for CMMs (co-ordinate measuring machines) and gauging systems
- Gauging systems for comparative measurement of machined parts
- High speed laser measurement and surveying systems for use in extreme environments
- Laser and ballbar systems for performance measurement and calibration of machines
- Medical devices for neurosurgical applications
- Probe systems and software for job set-up, tool setting and inspection on CNC machine tools
- Raman spectroscopy systems for non-destructive material analysis
- Sensor systems and software for measurement on CMMs
- Styli for CMM and machine tool probe applications



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