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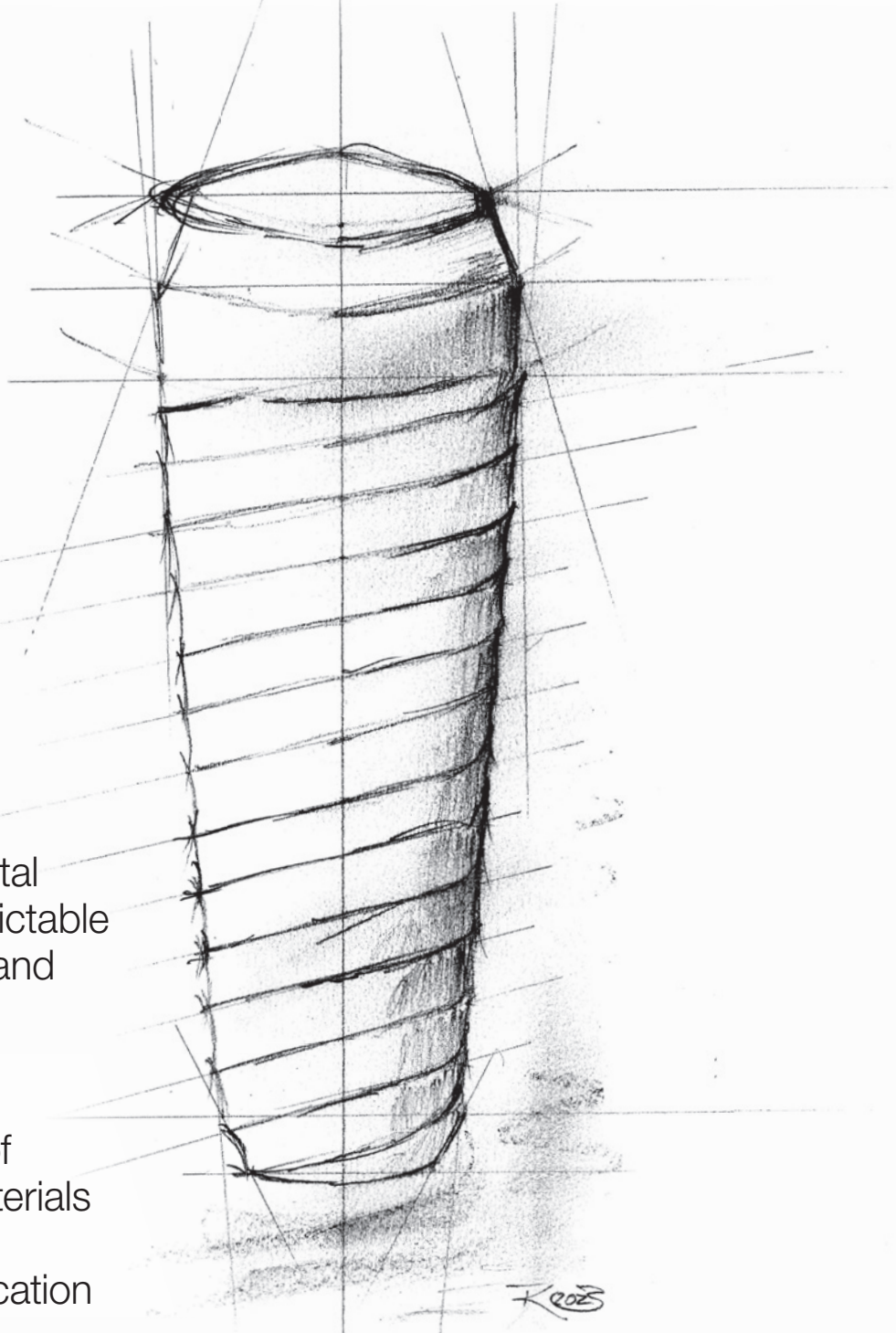
international magazine of oral implantology



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Dr Georg Bach

President of the DGZI

A great congress in Hamburg

Dear colleagues and friends,

We are looking back on a fantastic DGZI annual congress!

Once again, the venerable Hanseatic city of Hamburg proved to be a good venue for the DGZI—a significantly increased number of participants, a consistently excellent atmosphere that ran like a golden thread through the two content-packed days and an extremely interesting programme—all of which is very pleasing! The oldest European implantology society will have very fond memories of Hamburg and would like to thank everyone involved—it really has been a pleasure.

My own highlight was our many foreign guests and partners, that we were finally able to welcome back to our annual congress after the coronavirus pandemic.

I will remember for a long time the cheerful discussions with the large Japanese delegation on the eve of the congress. In addition to the enhanced travel opportunities for the representatives of our foreign partners, we were also able to get the expert exams back on track in Hamburg and award our young colleagues the much-desired qualification “made in Germany”.

Another high point was the presentation of the Implant Dentistry Award. The outstanding papers submitted in advance by young female scientists were so impressive that the award ceremony was “spoilt for choice”. Congratulations to the two award winners once again!

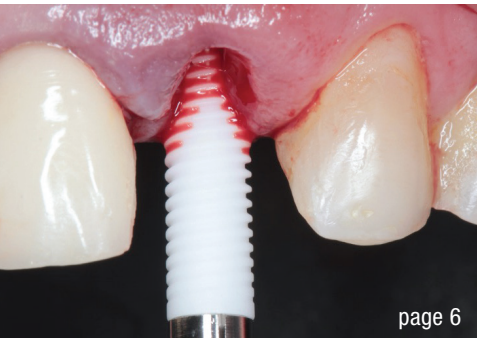
So you see, I came back from Hamburg with a whole package of positive emotions and I’m certainly not the only one! And as we all know, the next congress is just around the corner—next year we’ll be moving to the Rhineland, where the big DGZI family will be meeting in Düsseldorf.

Enjoy reading the *implants* magazine!

Yours,

Dr Georg Bach

President of the German Association of Dental Implantology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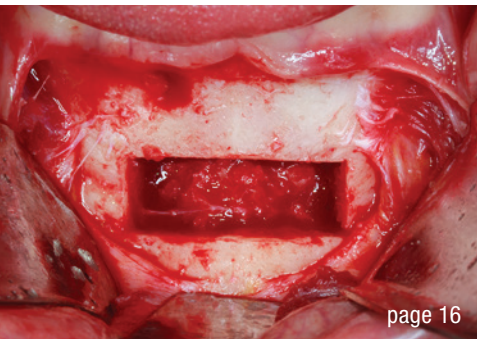
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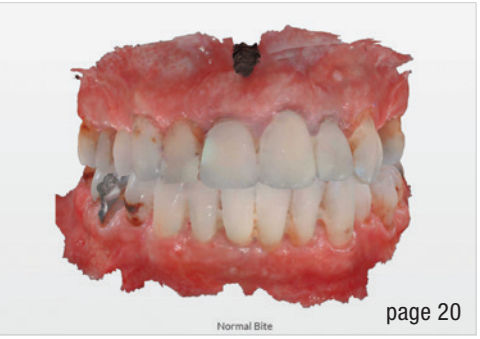

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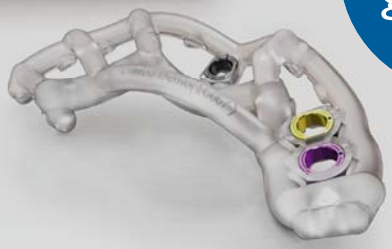

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[1] Semper-Hogg, W, Kraft, S, Stiller, S et al. Analytical and experimental position stability of the abutment in different dental implant systems with a conical implant–abutment connection Clin Oral Invest (2013) 17: 1017
[2] Semper Hogg W, Zulauf K, Mehrhof J, Nelson K. The influence of torque tightening on the position stability of the abutment in conical implant-abutment connections. Int J Prosthodont 2015;28:538-41

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Immediate placement and loading of ceramic implants in the aesthetic region: One-year follow-up—two case reports

Drs Alexandre Marques Paes da Silva, Dennis de Carvalho Ferreira, Thamires Alves Silva, Mayla Kezy Silva Teixeira, Daniel de Moraes Telles & Eduardo José Veras Lourenço, Brazil

In the late 1990s, yttria-stabilised zirconia (Y-TZP) emerged as a versatile and promising material with wide applicability in implant dentistry. Among the advantages of this material, its white colour and opacity stand out, these properties allowing it to mimic the appearance of natural teeth. Owing to its mechanical properties, mainly the ability to withstand high masticatory loads, zirconia has been used not only for creating restorations but also for the manufacture of ceramic implants.[1]

Y-TZP implants, in addition to being resistant and aesthetic, are highly biocompatible implants, have low affinity for bacterial plaque, are capable of stimulating osteogenic cells during the osseointegration process and boast corrosion resistance and radiopacity.[2] These characteristics have made these ceramic implants a possible substitute for titanium implants in oral rehabilitation, achieving predictable and reliable results.[3] The aim of the present study is to report two clinical cases of ceramic implantation in the aesthetic region using a surgical and prosthetic approach free of metal.

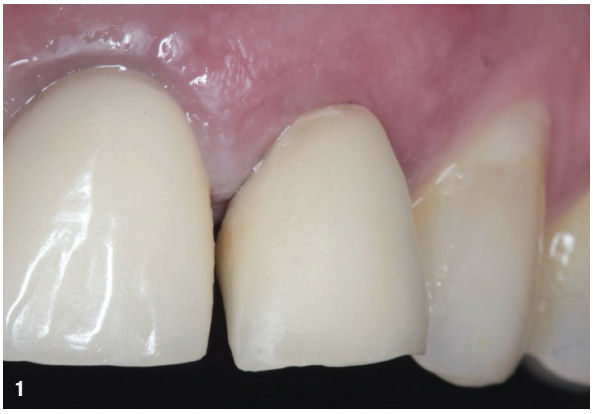
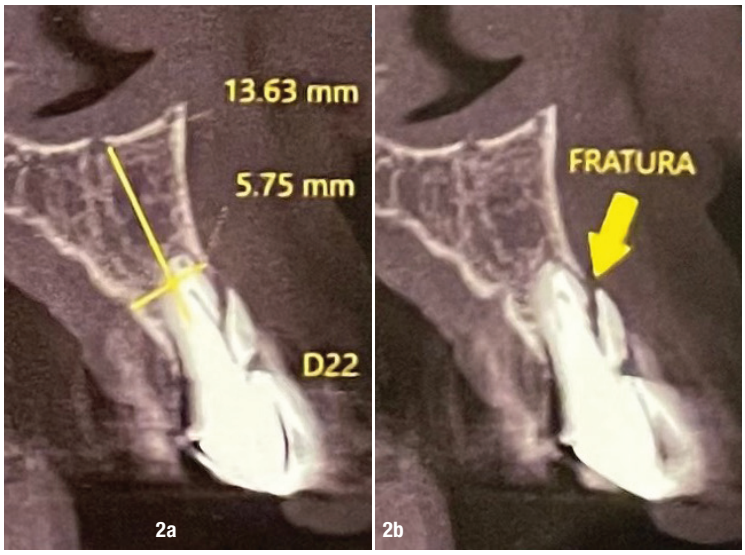


Fig. 1: Situation on initial clinical examination.



Figs. 2a & b: CBCT image showing the vertical root fracture.

Case reports

The patients were referred to one private clinical centre in Rio de Janeiro in Brazil with the need for extraction and immediate placement and loading of single implants in the aesthetic region. In order to carry out the correct planning and diagnosis, the patients were asked to undergo a CBCT scan, a periapical radiograph and intraoral photographs. The patients were non-smokers and were in good general health, without any systemic condition. Although the patients had good plaque control, they underwent supragingival scaling and root planning. This study was submitted to the ethics committee of the Universidade do Estado do Rio de Janeiro and approved (No. 5.598.463). The patients were previously invited to participate in and informed about the study and signed informed consent to participate, and all ethical aspects were followed.

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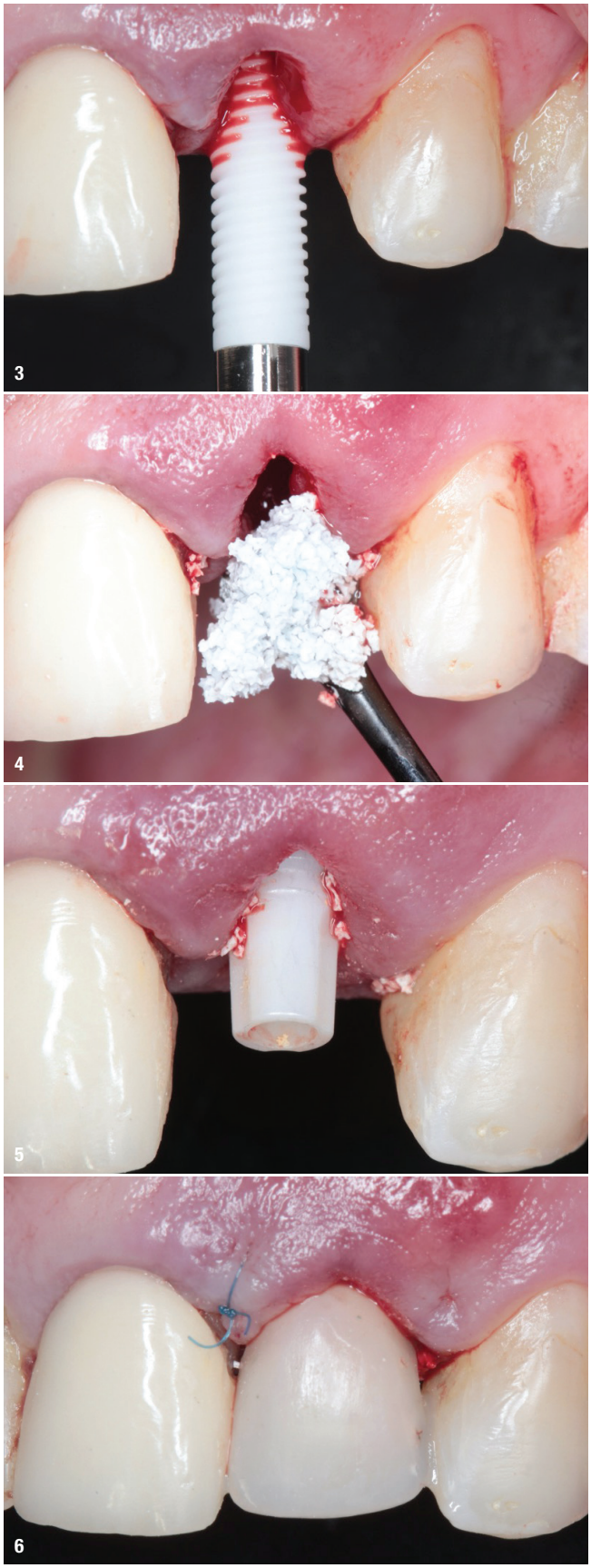


Fig. 3: Placement of the Zi implant. **Fig. 4:** Filling of the gap with bone grafting material. **Fig. 5:** Cemented zirconia abutment. **Fig. 6:** Immediate post-op situation with the provisional crown cemented.

Case 1

A 66-year-old female patient who was a smoker presented with the main complaint of a broken anterior tooth. On clinical examination, it was noted that the maxillary left lateral incisor had a metal-ceramic crown with a partially displaced cast metallic core (Fig. 1). The CBCT examination showed the presence of a vertical root fracture due to recurrent caries (Fig. 2). Given the clinical and radiographic situation, the proposed treatment was the extraction of the tooth in question, followed by immediate placement of a ceramic implant and immediate restoration with a crown.

The extraction was performed atraumatically with the aid of periotomes and forceps and a 3.75 × 13.0 mm two-piece ceramic implant (Zi, Neodent) was placed in the fresh alveolus (Fig. 3). The insertion torque was 35 Ncm, and this primary stability allowed for immediate loading. It should be noted that the implant was placed according to the manufacturer's recommendations at the level of the bone crest, and the gap was filled with bone substitute (maxresorb, botiss biomaterials; 0.5 cm^2 of 0.5–1.0 mm; Fig. 4). A 4.5 × 5.0 × 2.5 mm (regular) zirconia abutment (Zi CR abutment) was seated (Fig. 5), and a provisional restoration was made with light-polymerising composite resin and cemented on the abutment (Fig. 6). At the end of the surgical procedure, a radiograph was taken (Fig. 7).

The three-month postoperative period was uneventful, and after this period, the patient returned to begin the final prosthetic phase. The final prosthesis was fabricated from monolithic zirconia using a digital workflow (Virtuo Vivo intra-oral scanner, Straumann; Figs. 8 & 9) and cemented on to the abutment with a dual adhesive cement (RelyX U200, 3M; Fig. 10). After 12 months of follow-up, the periapical radiograph showed the stability of the bone (Fig. 11).

After cementing the crown, it was observed that a new crown was needed for the adjacent tooth, the maxillary left central incisor, owing to the discrepancy in colour and dental anatomy. This prosthesis was also fabricated from monolithic zirconia using a digital workflow (Fig. 12) and cemented onto the prepared tooth with a dual adhesive cement (RelyX U200; Fig. 13).

Case 2

A healthy 70-year-old female patient presented with the main complaint of toothache in the region of the maxillary left lateral incisor. Upon clinical examination, it was noted that the tooth had a metal–ceramic crown and had not undergone endodontic

Fig. 7: Post-op radiograph. **Fig. 8:** Scan body in position for intra-oral scanning. **Fig. 9:** Intra-oral scan. **Fig. 10:** Cementation of the final zirconia crown. **Fig. 11:** Periapical radiograph showing stability of the bone after 12 months. **Fig. 12:** Intra-oral scan of the maxillary left central incisor for a new crown. **Fig. 13:** Situation at conclusion of the case.

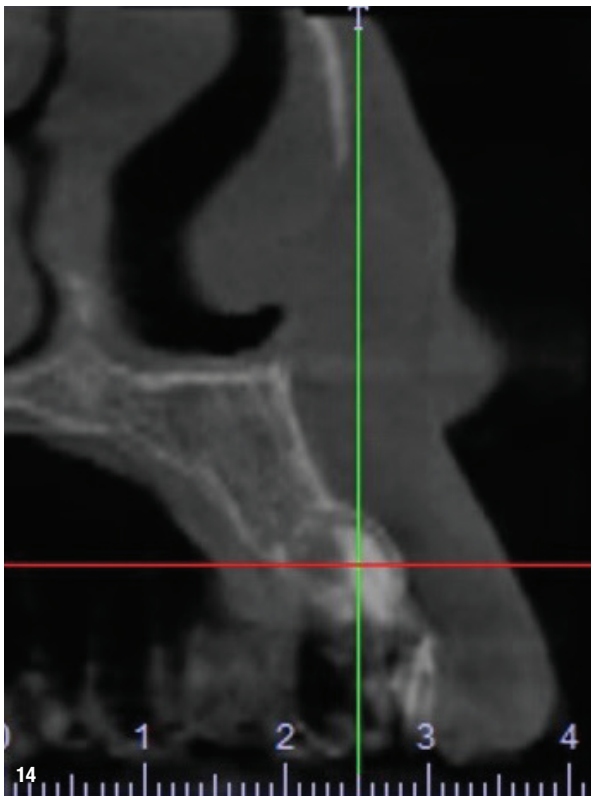


Fig. 14: CBCT image showing periapical periodontitis.

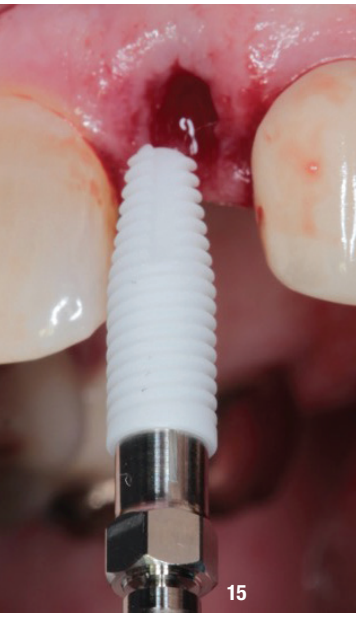
treatment. The CBCT scan showed the presence of an endodontic lesion of greater than 5 mm, and the patient wanted the tooth extracted (Fig. 14). Given the clinical and radiographic situation, the proposed treatment was tooth extraction, immediate placement of a ceramic implant and immediate restoration with a 17° angulated abutment and a provisional crown.

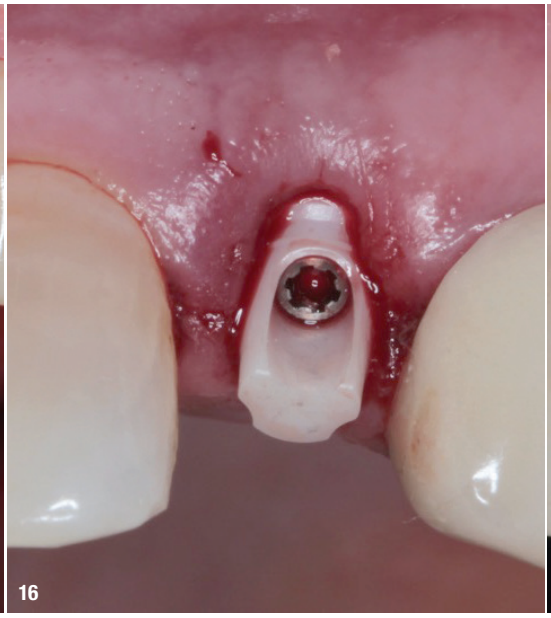
Like in the previous clinical case, the extraction was performed atraumatically, and curettage and cleaning of the fresh alveolus was performed. After that, a 4.3 × 13.0 mm two-piece ceramic implant (Zi) was placed to an insertion torque of 45 Ncm (Fig. 15). A 4.0 × 5.0 × 2.5 mm (narrow) 17° angulated zirconia abutment (Zi CR abutment) was seated (Fig. 16), and a provisional restoration was made with self-polymerising resin and cemented on to the abutment (Fig. 17). At the end of the surgical procedure, a radiograph was taken (Fig. 18).

The three-month postoperative period was uneventful, and after this period, the patient returned to begin the final prosthetic phase. The final prosthesis was fabricated from lithium disilicate (IPS e.max, Ivoclar Vivadent) using an analogue workflow with impression material (addition-cured silicone, Yller) and cemented on to the abutment with a dual resin cement (RelyX U200; Fig. 19). Prior to cementation, the health of the peri-implant tissue around the ceramic implant was observed, as was the maintenance of the soft tissue, including the mesial and distal papillae (Fig. 20). After 12 months, the patient returned and a radiograph was taken, on which the maintenance of the bone around the implant was observed (Fig. 21).

Discussion

The literature shows that titanium implants have achieved excellent and predictable results over the last decades, are biologically tolerable and exhibit excellent mechanical properties. However, it is important to point out that titanium implants have aesthetic disadvantages, especially when placed in patients with a thin gingival biotype in the anterior region. Ceramic implants avoid the metallic shadow of the implant or abutment under the tissue.[4]





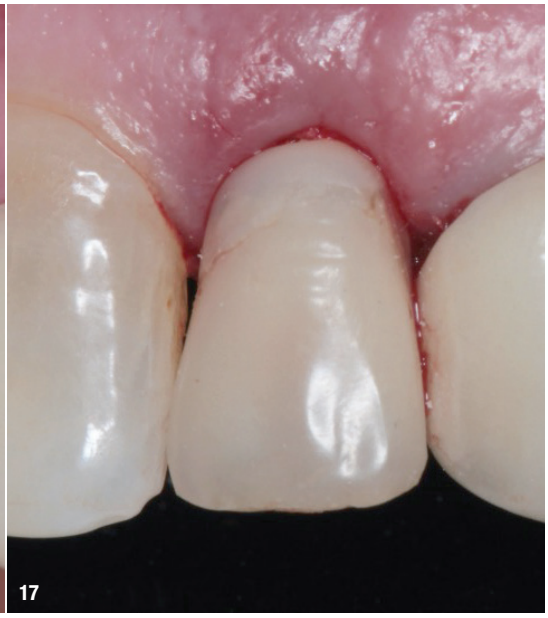


Fig. 15: Placement of the Zi implant. **Fig. 16:** Cemented zirconia abutment. **Fig. 17:** Immediate post-op situation with the provisional crown cemented.

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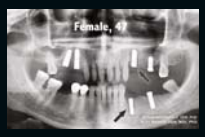

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Over the years, ceramic materials have been the subject of investigation and clinical application as a potential alternative to titanium, and increasingly, zirconia has stood out as a promising alternative.[5] Among its beneficial properties is its colour, which is similar to that of natural teeth, making this material especially relevant in the aesthetic region,[6] which we observed in the present study. This similarity enables adequate light transmission at the critical interface between the marginal gingival tissue and prosthetic components.[6]

With the development of CAD/CAM, this high-strength ceramic is becoming the first choice for restoration of implants in the aesthetic region.[7] In addition to its aesthetic advantages, monolithic zirconia has several excellent mechanical characteristics, such as high fracture toughness, resistance to fatigue, high flexural strength, significant corrosion resistance and radiopacity,[8] strengthening its viability for use for a range of restorations, from single crowns to complete dentures, supported on implants in the anterior and posterior regions.[9] In both regions, zirconia crowns have shown high survival rates.[10]

In Case 1, a digital workflow was employed, and a monolithic zirconia crown was fabricated, whereas in Case 2, an analogue workflow was followed, and a lithium disilicate crown was fabricated. In both cases, satisfactory aesthetics were achieved; however, the possibility of performing a digital workflow, in addition to being more accurate regarding the final result, reduces the number of adjustments and is more comfortable for the patient.[7]

Biologically, zirconia provides reduced plaque build-up and excellent hard- and soft-tissue integration, equivalent to that of titanium.[11] In the current literature, studies show that zirconia implants present similar or even better results regarding these measures when compared with titanium implants.[12,13] Furthermore, zirconia, like titanium, is a biocompatible material and favours the health of the peri-implant soft tissue,[14] as was observed after 12 months of follow-up in the two cases reported here. In Case 2, we observed the health of the soft tissue around the ceramic implant, particularly the collagen fibres present in the region.

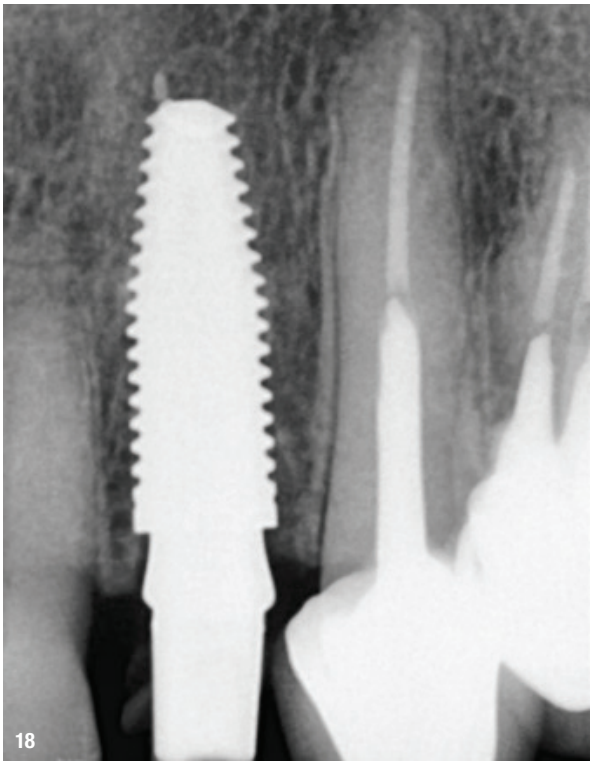
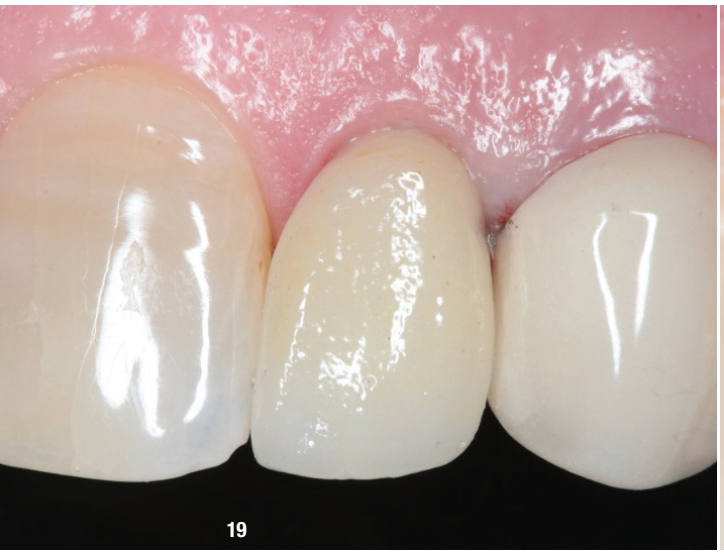


Fig. 18: Post-op radiograph.

Initially, ceramic implants were predominantly one-piece implants.[15] These single-body implants have reduced



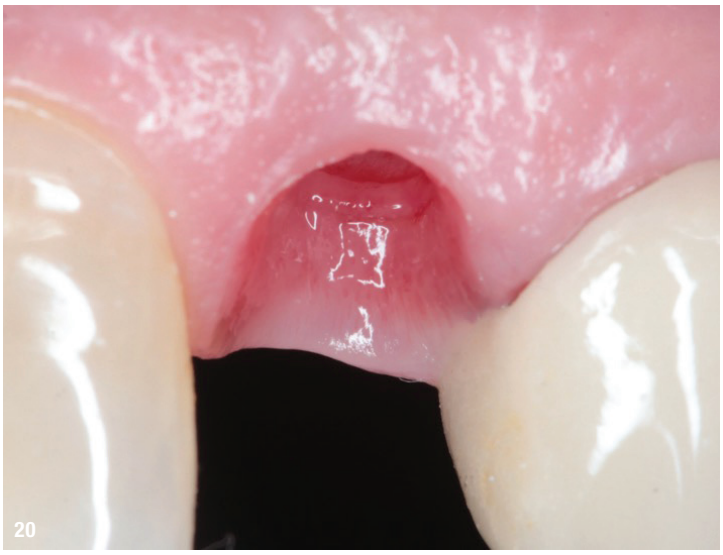


Fig. 19: Cementation of the final lithium disilicate crown. **Fig. 20:** Healthy soft tissue around the implant.

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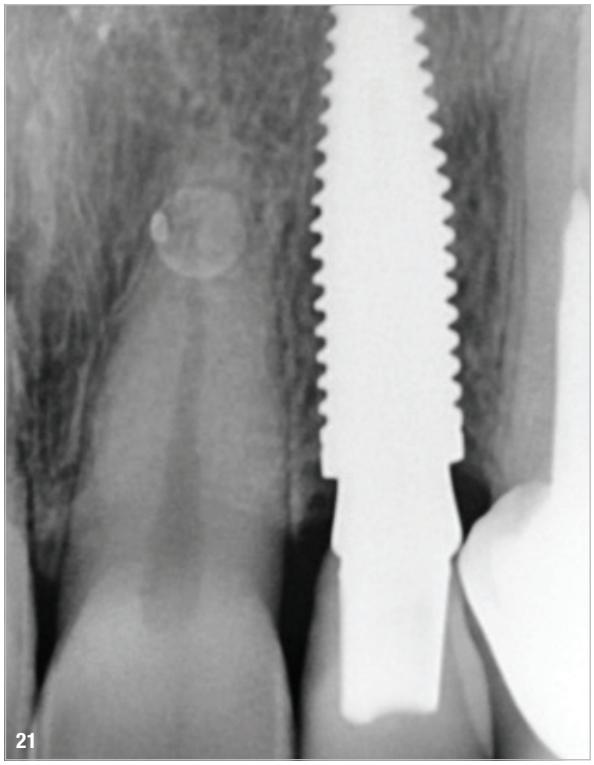

Fig. 21: Final radiograph.

prosthetic versatility, since there is no possibility of angling the prosthetic component, which may be critical in the aesthetic region.[16] However, these single-piece implants have the advantage of having a transmucosal abutment as part of the implant unit, thus avoiding the presence of an implant–abutment micro-gap and nullifying the micro-movements between the abutment and the implant.[17] There are few studies on single-piece ceramic implants with long follow-up periods, and most of them have a low sample size.[18]

In order to address the limitations of single-piece implants, a separate implant body and abutment were designed, thus providing greater prosthetic options. Two-piece zirconia implants have been found to have high success rates, similar to those found in titanium implants.[19] Zirconia abutments are widely used in regions with high aesthetic demand, presenting high biocompatibility and mechanical resistance.[20] In the present study, it was decided to use a two-piece implant in order to have more prosthetic options, and Case 2 required the use of an angulated abutment owing to the positioning of the bone. In this case, it would have been difficult to use a one-piece implant without the need for abutment preparation.

Conclusion

The main objective of this case report was to present the clinical and radiographic performance of ceramic implants placed in the aesthetic region in two patients, who were followed up for 12 months. The soft and hard tissue were maintained over the follow-up period.

The Zi two-piece ceramic implant system used in the two cases described proved to be a safe and reliable alternative in oral rehabilitation of the aesthetic region. Further studies will need to be carried out to confirm our findings, and the cases presented here will continue to be monitored.

Literature

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Extreme maxillary bone reconstruction with CERASORB Bioactive—a case report

Drs Fernando Duarte & Carina Ramos, Portugal

Ossifying fibroma is classified as, and behaves like, a benign bone neoplasm. It is often considered to be a type of fibroosseous lesion. This bone tumour consists of highly cellular, fibrous tissue that contains varying amounts of calcified tissue resembling bone, cementum or both.[1] Owing to the presence of both bone and cementum-like tissue in ossifying fibromas, these lesions are described using the terms "ossifying fibroma", "cementoossifying fibroma" and "cementifying fibroma".[2] Nonetheless, the consensus is that these three terms describe the same underlying type of lesion.[3,4]

In most cases, ossifying fibroma is slow-growing, but it is occasionally aggressive, particularly its juvenile subtypes. Additionally, its growth is usually concentric, and it is well demarcated from the adjacent bone. Some lesions may grow to become massive, causing considerable aesthetic and functional deformities. Clinically, ossifying fibroma is usually asymptomatic and is often found accidentally in routine dental examinations.

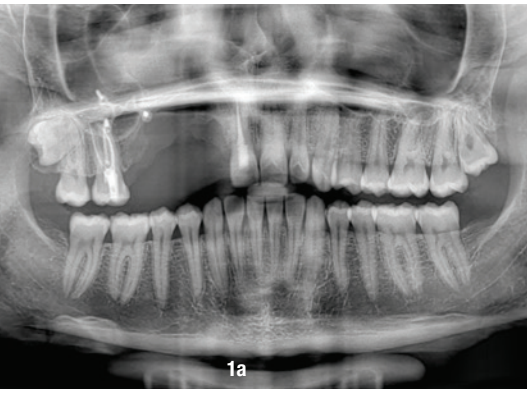
Ossifying fibroma predominantly affects the facial bone, most commonly in the mandible, where it arises apical to the premolars and molars and superior to the mandibular canal.[2] Among the other cranial and facial bones, the periorbital, frontal, ethmoid, sphenoid and temporal bones are also relatively common sites of this tumour.[4,5]

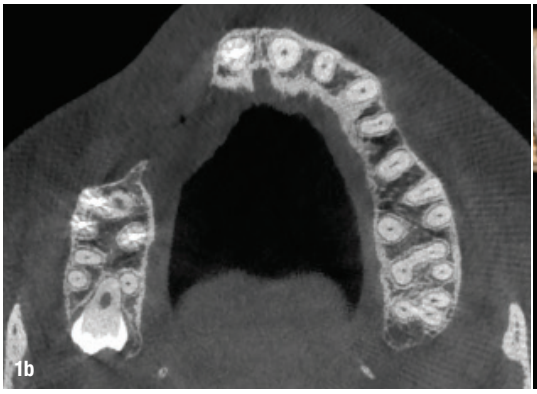
Ossifying fibroma most commonly occurs in patients in the second to fourth decades of life, although it may arise in children and adolescents, as well as in older adults.[2] It shows a predominance among females.[6]

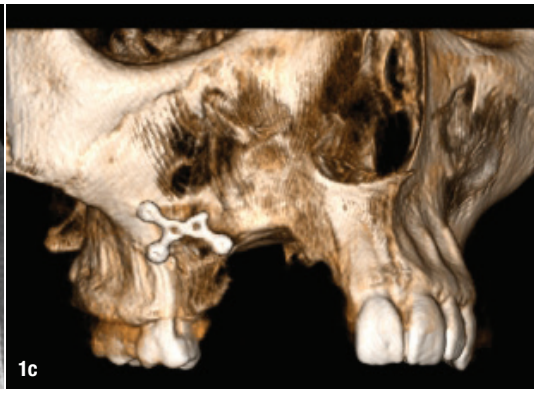
Classification

In 1968, Hamner et al. analysed 249 cases of fibroosseous jaw lesions of periodontal membrane origin and classified them.[7] In 1973, Waldron and Giansanti reported 65 cases (of which 43 had adequate clinical histories and radiographs) and concluded that this group of lesions was best considered a spectrum of processes arising from cells in the periodontal ligament.[6] In 1985, Eversole et al. described the radiographic characteristics of central ossifying fibroma, and two major patterns were noted, expansile unilocular radiolucencies and multilocular configuration.[8,1]

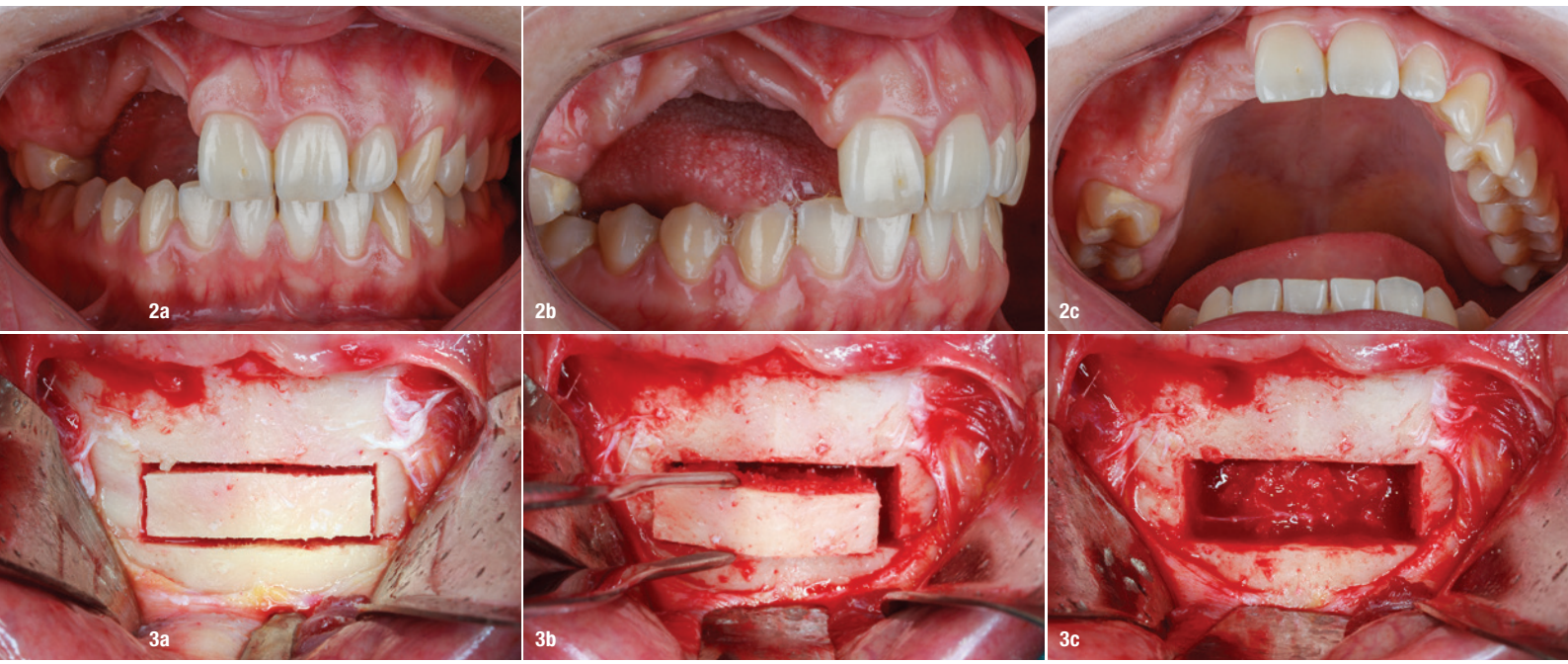
In 1971, the World Health Organization (WHO) suggested the classification of cementum-containing lesions into four types: fibrous dysplasia, ossifying fibroma, cementifying fibroma and cementoossifying fibroma.[2] In a subsequent WHO classification, benign fibroosseous lesions of the oral and maxillofacial regions were divided into osteogenic neoplasms or non-neoplastic bone lesions, the former category including cementifying ossifying fibroma.[2]







Figs. 1a–c: Initial orthopantomography and computed tomography.



Figs. 2a–c: Clinical aspect of first quadrant bone defect. **Figs. 3a–c:** Rectangular osteotomy in the chin area.

However, the term "cementifying ossifying fibroma" was simplified to "ossifying fibroma" in the 2005 WHO classification system.[9]

Radiographic features

In a study by Liu et al. the radiographic characteristics of the tumour showed two patterns: cystic lesions (either unicystic or multicystic) and mixed-density lesions. The predominant radiographic features of ossifying fibroma are a round or oval well-defined, expansile mass with a corticated border and a variable degree of internal radiopacity.[1]

The internal aspect of these lesions can be granular, resembling fibrous dysplasia, and they may have a thin, radiolucent periphery, representing a fibrous capsule. This can result in the expansion of the outer cortical plate of bone. The density of these lesions is mixed, and the internal structure may be a mixture of radiolucent and radiopaque tissue.[1] Radiographically, ossifying fibroma most frequently appears as a well-defined mixed radiolucent and radiopaque lesion.

Differential diagnosis

The differential diagnosis includes benign mixed radiolucent and radiopaque neoplasms, and the diagnosis is determined by the clinical and radiographic behaviour.[2] The differential diagnosis depends on the degree and pattern of internal radiopacity. In many cases, CBCT images are helpful for diagnosing these lesions.[2] A diagnosis of fibrous dysplasia or periapical osseous dysplasia may be considered, and occasionally, a diagnosis of cementoblastoma.

Fibrous dysplasia refers to the replacement of normal bone with fibrous tissue containing foci of immature woven bone. Although fibrous dysplasia shows poorly defined expansion, the general shape of the involved bone is maintained. In contrast, ossifying fibroma displays tumour-like, concentric expansion.[2]

However, periapical osseous dysplasia is often multifocal, whereas ossifying fibroma is not. A wide sclerotic border, as well as a more undulating expansion, is more characteristic of the slow-growing periapical osseous dysplasia. The epicentre of periapical osseous dysplasia is located at the apex of the tooth, within the alveolar process.

Bone reconstruction

The treatment of choice for an ossifying fibroma is resection, requiring subsequent bone reconstruction. CERASORB Bioactive (curasan) is a bioactive synthetic, porous, biocompatible ceramic material made for filling, bridging and reconstruction of bone defects and augmentation of the atrophied alveolar ridge. This fully resorbable material provides the potential to increase bioactivity.[10] This new material with phase-pure beta-tricalcium phosphate technology is doped with silicate to enhance its mechanical stability and offers high open-celled porosity of approximately 75% for immediate start of osseointegration and is completely resorbed after four to six months.

Platelet-rich fibrin is a therapeutic blood matrix obtained by selective centrifugation and acts as an adjuvant in tissue repair. In order to obtain these fibrin matrices for the case presented in this article, six samples of autologous blood were collected in 10 mL pure glass dry tubes (Montserrat) and two blood samples in polystyrene dry tubes (Greiner Bio-One). These were centrifuged in the Fibrin System centrifuge (Ortoalresa) according to the methodological proposal of Duarte de Almeida and de Oliveira, which uses relative centrifugal force of 200 ×g for ten minutes to obtain two physical forms of fibrin, a polymeric or solid gel form and a monomeric or temporary liquid phase form, in a single centrifugation step.[11]

Clinical case

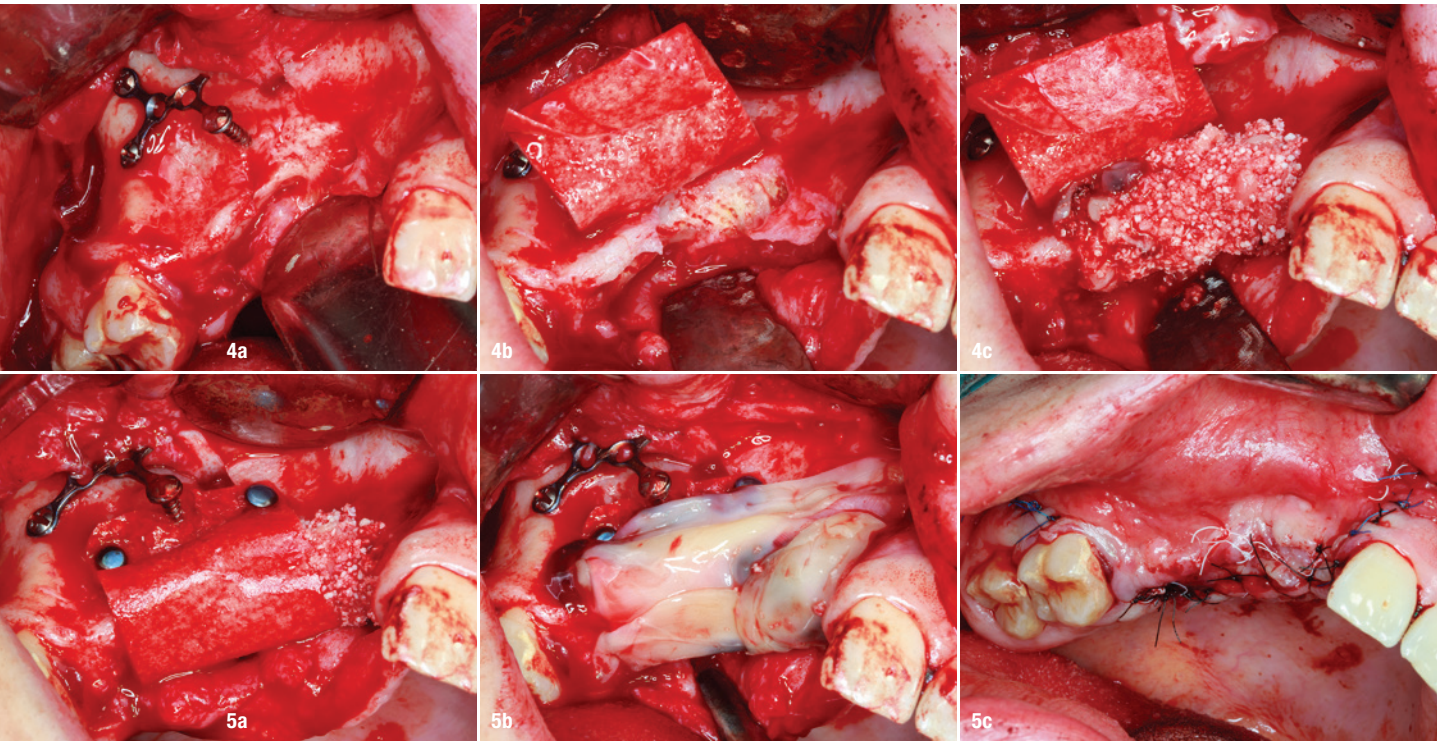
A 26-year-old female patient attended an oral and maxillofacial surgery consultation at the Clitrofa medical, dental and surgical centre in Trofa in Portugal for bone reconstruction of the maxillary right quadrant. The patient had been diagnosed with ossifying fibroma. It had been excised with a safe bone margin, and the bone defect was reconstructed with an autogenous fibula graft in the same surgery. This had failed after a month owing to bone exposure. The osteosynthesis plate used in graft fixation was present.

Anamnesis found no allergies or use of medications. On extra-oral clinical examination, a normal appearance was observed. On intra-oral clinical and radiographic examination (dental panoramic tomogram and CBCT), a massive bone defect was noted in the anatomical areas of teeth #15–12 (Figs. 1a–2c).

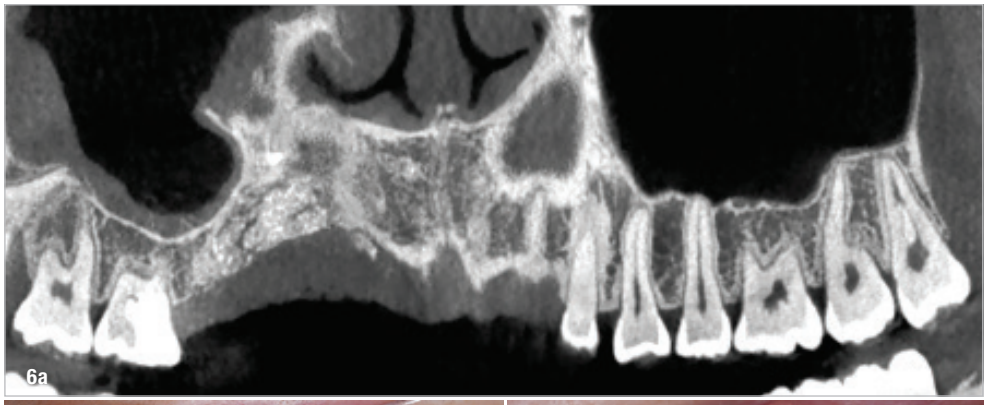
Two vertical and two horizontal osteotomies were performed in the symphyseal and parasymphyseal region to delimit the bone area to be grafted. This rectangular osteotomy was performed according to the bone availability evident in the CBCT scan (Figs. 3a–c).

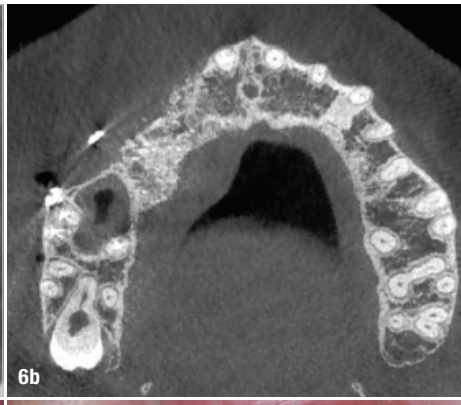
Bone reconstruction was performed by combining this autogenous bone and CERASORB Bioactive in a 50:50 ratio. The bone grafting material was mixed with the platelet-rich fibrin to create sticky bone, facilitating handling and application and allowing immediate adhesion to the defect site. The use of platelet-rich fibrin in the grafting process allows one to exploit its properties, especially in supporting the inflammatory response, immune response, tissue repair, tissue reorganisation and angiogenesis.

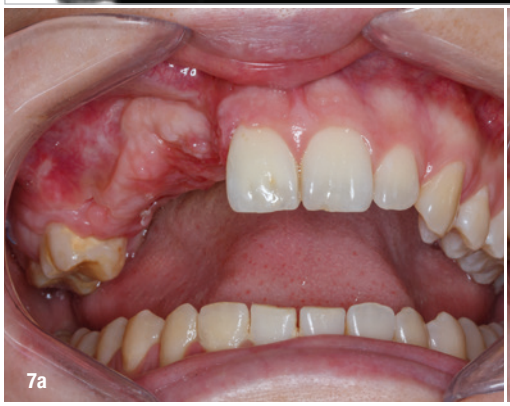
An EPI-GUIDE membrane (curasan) was used to cover the grafted site. This is a non-biological, resorbable hydrophilic membrane containing a 3D structure important for barrier function. Its 3D constructed density gradient is designed to attract and stabilise fibroblasts and epithelial cells while allowing permeable nutrients through the membrane. To ensure reliable positioning and fixation of the membrane, 5 mm Ti-SYSTEM pins (curasan) were used (Figs. 4a–c).

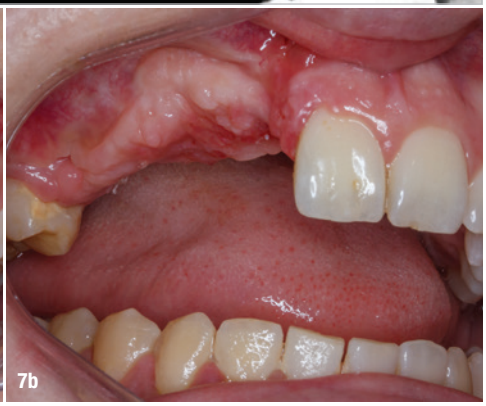


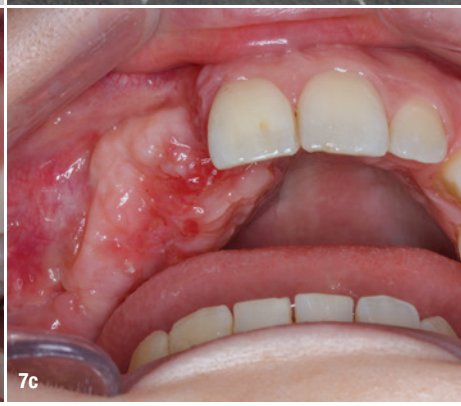
Figs. 4a–c: Sticky bone and EPI-GUIDE membrane fixed with Ti-SYSTEM 5 mm pins. **Figs. 5a–c:** Suture with undyed monofilament non-absorbable PTFE 4/0 and non-absorbable nylon 5/0.











Figs. 6a & b: Final computed tomography. **Figs. 7a–c:** Final clinical aspect of first quadrant bone reconstruction.

The autologous platelet-rich fibrin membranes were placed over the site to provide an extra-protected environment for bone regeneration in the defect area and to support new bone growth by presenting a barrier to the infiltration of soft tissue and promoting the growth of osteogenic cells in the bony defect (Figs. 5a–c). Suturing was performed with simple sutures using undyed non-resorbable (#4/0 PTFE) and non-resorbable monofilament suture material (#5/0 nylon; Figs. 6a & b).

The patient underwent systemic antibiotic, analgesic and anti-inflammatory therapy for eight days. Regarding post-operative care, she was instructed to maintain strict oral hygiene. The CBCT scan and clinical examination during the postoperative period of six months showed evidence of new bone formation (Figs. 7a–c).

Conclusion

This new biomaterial was developed for resorption and new bone formation to mimic autologous bone. It shows superior handling with rapid hydration with the surgeon's preferred fluids, including autologous fluids, growth factors and antibiotics for various surgical indications. In this case report, bioactive silicate coupled with high-porosity beta-tricalcium phosphate appears to have led to enhanced bone formation. A longer follow-up and case series will be needed to corroborate the encouraging preliminary results of this new biomaterial.

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Literature

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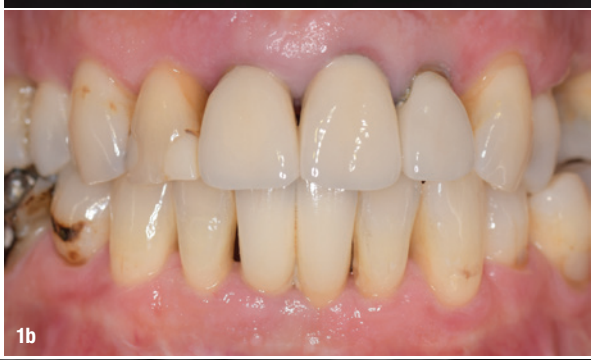
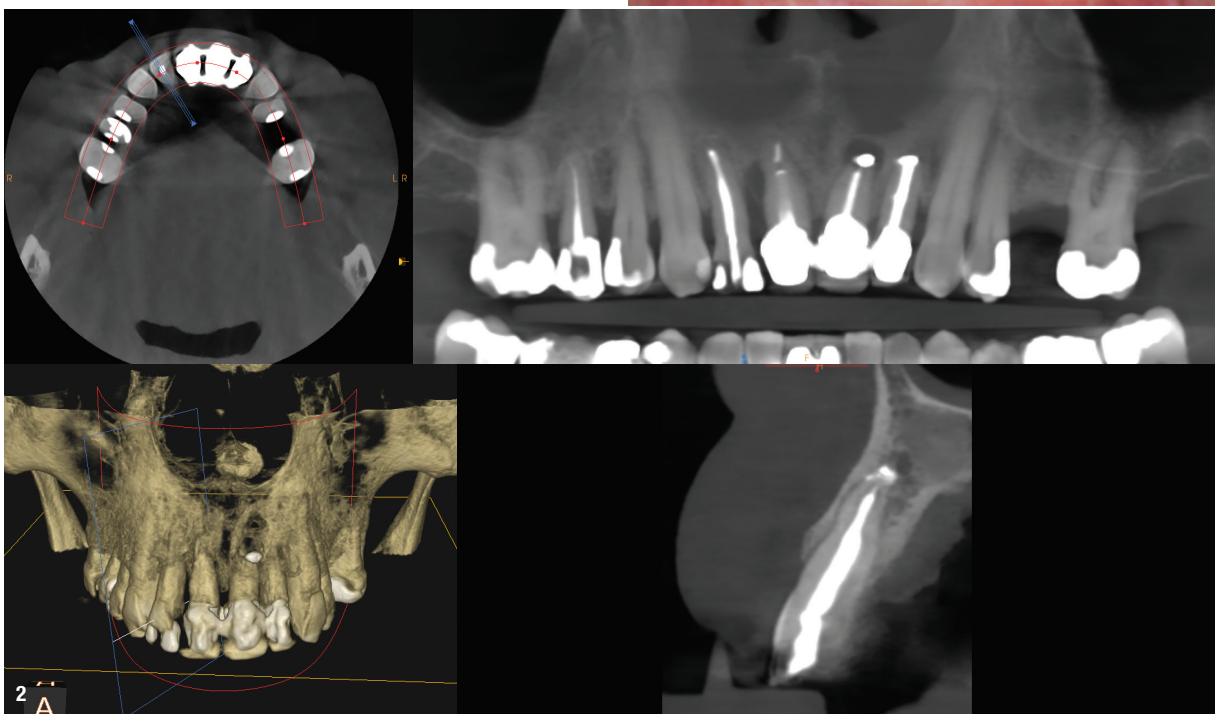
A fully guided digital workflow for predictable implant planning and placement

Dr Beat R. Kurt, Switzerland

A 62-year-old male patient was referred to my practice for implant planning and treatment in the maxillary anterior region. The teeth in the maxillary anterior region had all undergone endodontic therapy, and teeth #11-22 had received crowns owing to an accident that had occurred 30 years before. The patient reported pain and was conscious that tooth #21 was mobile (Figs. 1a & b).



The first step was to obtain a CBCT scan of the maxillary arch, which revealed periapical pathology in teeth #12-22 (Figs. 2 & 3). Furthermore, tooth #21 exhibited significant loss of buccal bone, and a small piece of amalgam was identified in the bone near tooth #21. After a thorough analysis of the radiographic findings, a treatment plan was established to extract teeth #12-22 and perform ridge preservation to reduce bone loss in the extraction sites.



Figs. 1a & b: Initial situation. **Fig. 2:** Initial CBCT scan of the maxillary arch.

Fig. 3: Initial CBCT scan. Coronal view of tooth #21 showing buccal bone loss. **Figs. 4a–c:** Digital impressions of the initial situation.

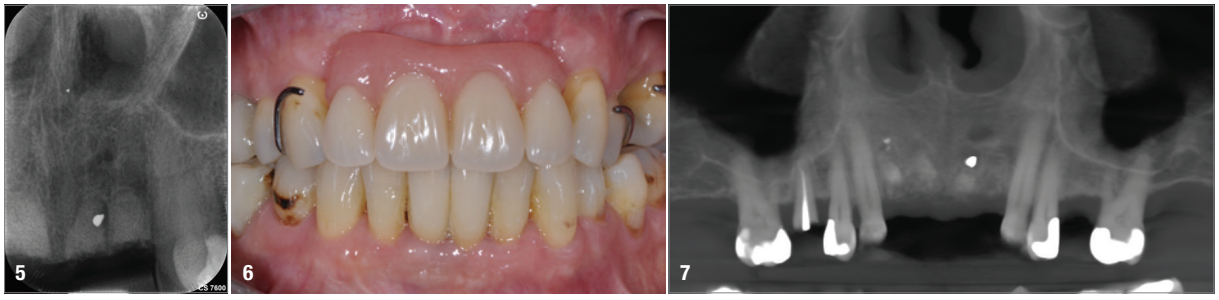
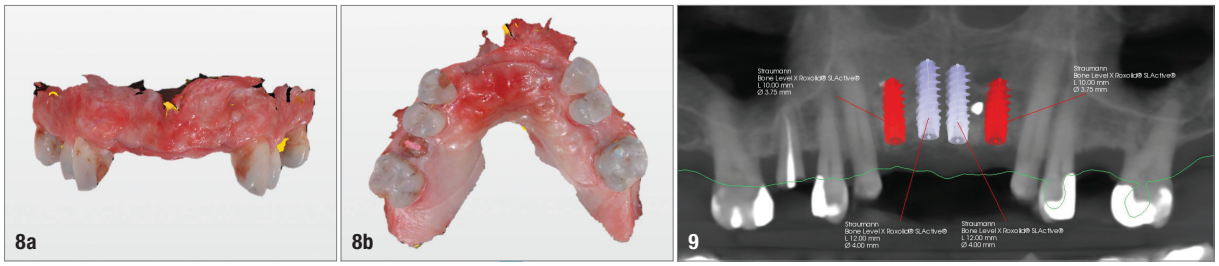


Fig. 5: Intra-oral radiograph after the extractions and ridge preservation. **Fig. 6:** Intra-oral image with the temporary prosthesis in place. **Fig. 7:** CBCT scan of the maxillary anterior region after the extractions.



Figs. 8a & b: Digital impressions after the extractions. **Fig. 9:** Implant planning for all four positions.

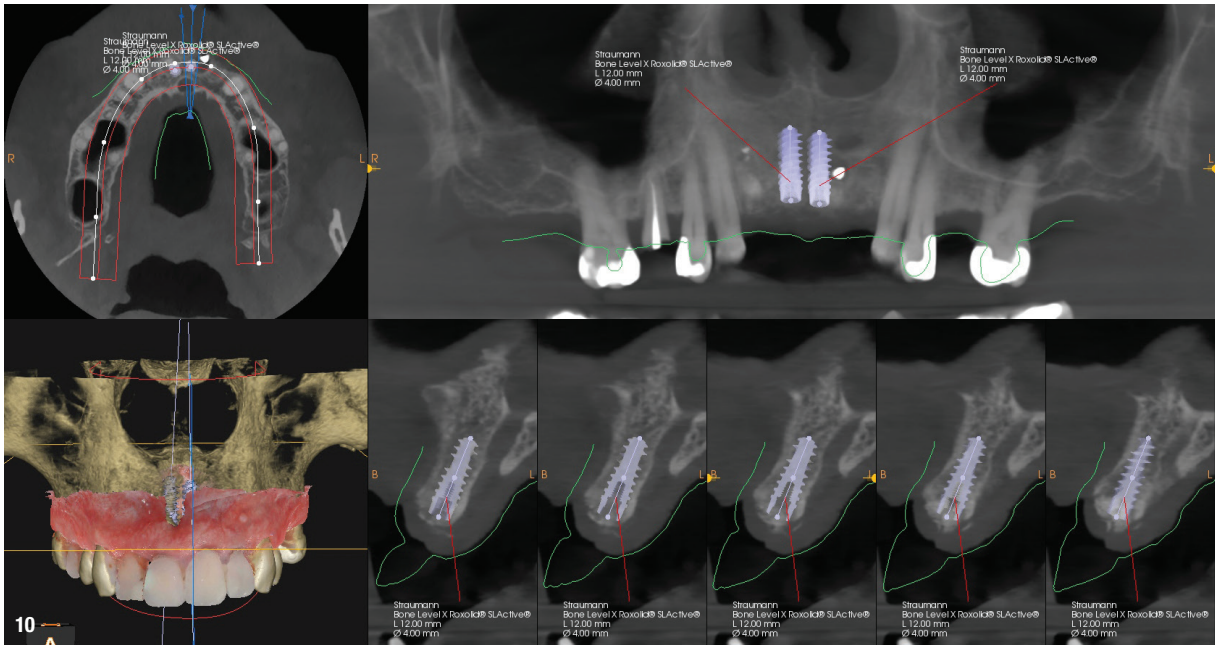
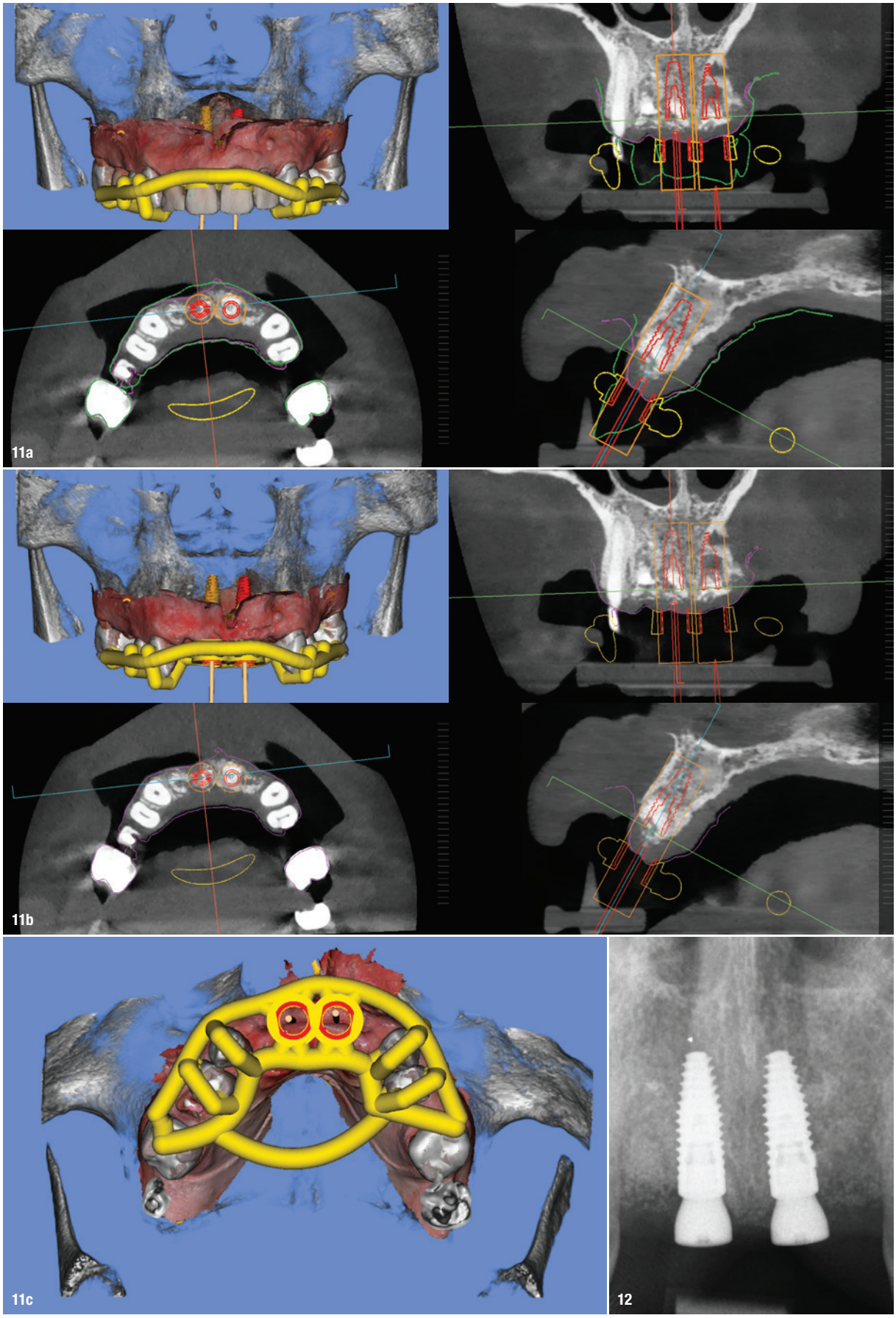
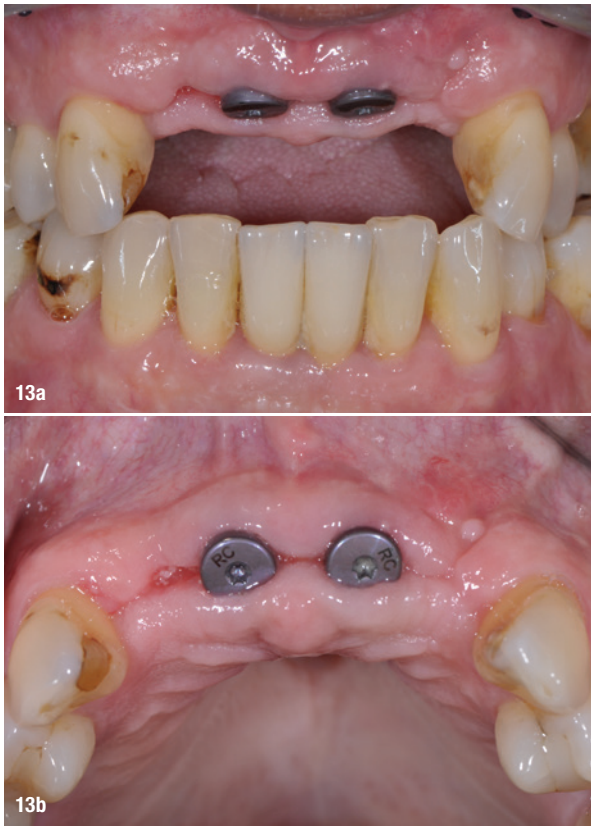


Fig. 10: Final planning for two implants with merged intra-oral scan and CBCT data.



Figs. 11a–c: Implant planning and guided surgical guide design. **Fig. 12:** Intra-oral radiograph of the implants after placement.



Figs. 13a & b: Intra-oral view of the implants with healing abutments after placement.

As is routine protocol in my dental practice, we captured a digital impression of the maxillary and mandibular arches with the DEXIS IS 3800 intra-oral scanner (Figs. 4a–c), along with intra-oral photographs to document the initial oral condition. These digital models were used for the fabrication of the temporary removable prosthesis.

Upon receiving approval from the insurance company for the proposed treatment plan, all four teeth were extracted. After the extractions, the extraction sockets were meticulously debrided with EthOss degranulation burs and filled with EthOss grafting material to promote primary closure and healing of the wound (Fig. 5).

To preserve both the aesthetic and functional aspects for the patient during the time between extraction of the teeth and the new bridgework, a temporary removable prosthesis was fabricated (Fig. 6). The patient's general dentist has also been working fully digitally for years, and the temporary prosthesis was made from a digital impression and printed models.

Two months after the extractions, we obtained a CBCT scan of the maxilla (Fig. 7) and captured digital impressions using our DEXIS IS 3800 intra-oral scanner (Fig. 8). These scans were essential for commencing the implant planning process and creating the surgical guide.

During the implant planning phase, we created a preliminary plan using 3D imaging software with a prosthetically driven implant planning approach (Figs. 9 & 10), and the plan was exported into surgical guide planning software for final planning and construction of the surgical drilling guide (Figs. 11a–c). The implants were planned in all four positions with the object of identifying the two most optimal and accessible sites for the placement of two implants and the corresponding bridge restoration.

After completion of the planning and drilling reconstruction, the surgical guide was 3D-printed with a Stratasys printer using MED610 resin (Stratasys). The two implants (4.1 x 12.0 mm Straumann Bone Level Tapered, Regular CrossFit, SLActive, Roxolid) were then placed utilising the Straumann guided surgery kit for precise guidance. The remaining piece of amalgam in the bone of tooth #21 was carefully removed—only a small piece in the gingiva remained (Fig. 12). The buccal bone was again thickened with EthOss, and the wound was closed with a semi-submerged technique, facilitating proper healing and integration of the implants (Figs. 13a & b).

After a ten-week osseointegration and healing period, the patient returned for a final assessment of the implant stability using the implant stability quotient measurement. The subsequent step will involve the completion of the final prosthesis, which will be performed by the patient's general dentist. To create the screw-retained monolithic bridge, a digital impression will be obtained using an intra-oral scanner, and the dental technician will also work fully digitally—as far as possible—for the final prosthesis.

about the author

Dr Beat R. Kurt is a paid consultant for DEXIS. The opinions presented are those of Dr Kurt. Dental Imaging Technologies Corp. is a medical device manufacturer and does not dispense medical advice. Clinicians should use their own judgement in treating their patients.

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Biocompatibility of CAD/CAM biomaterials for bone tissue engineering application

Dr Katharina Pippich, Katharina Hast, Adem Aksu, Stefanie Grom, Dr Tobias Wolfram, Frank Reinauer, Dr Dr Andreas Fichter, Dr Dr Achim von Bomhard, Germany

Large bone defects have so far mainly been treated with autogenous bone grafts. Owing to limited availability and donor site morbidity, research is ongoing into the development of various bone replacement materials. An advantage of CAD/CAM implants is the possibility of patient-specific engineering. Ceramics and polymers have been extensively investigated, but not all materials can be produced in a standardised and patient-specific way yet. In this study, a wide range of materials were investigated, all of which can be CAD/CAM manufactured and individually dimensioned in the clean room with standardised techniques using digital light processing, selective laser sintering and fused deposition modelling. The novelty of the materials is the compounding of these, including the special processing by 3D printing. Eight polymer and ceramic CAD/CAM materials—poly-L-lactic acid and calcium carbonate, poly-L-lactic acid and tricalcium phosphate, poly-L-lactic acid and polyglycolic acid and calcium carbonate, poly-D, L-lactic acid and magnesium, poly-D, L-lactic acid, beta-tricalcium phosphate (β-TCP) and hydroxyapatite, β-TCP and β-TCP'—were tested to evaluate the cytotoxic effects on human osteoblasts. Biocompatibility was tested using a proliferation assay, a cytotoxicity assay, an apoptosis assay and fluorescence microscopy. The ceramic-based scaffolds, in particular β-TCP, showed very high cell counts in the proliferation assay as well as rapidly falling apoptosis rates and offer significant potential for use for patient-specific bone replacement implants.

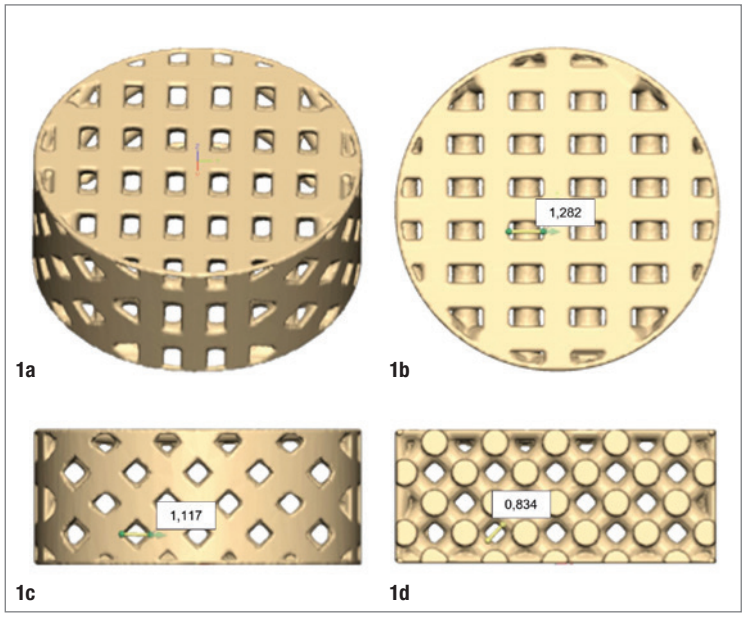

Fig. 1: Scaffold construction (sizes in mm). Scale bars = 1 mm. 3D view **(a)**, top view **(b)**, side view **(c)**, Cross section **(d)**.

Introduction

Bone defects often occur in the context of tumour resection, bone inflammation, malformation or trauma.[1] Autogenous bone transplantation continues to be the gold standard for the reconstruction of such defects. However, bone availability is limited in this case, and not inconsiderable donor site morbidity, including impaired wound healing, functional limitations, scarring and necrosis, can occur.[2] Research in the field of bone regeneration is steadily growing.[3] Of great interest are biomaterials, which being bone replacement materials, avoid the creation of donor sites and the associated complications and which, owing to their osteoconductive properties and suitable architecture, represent a viable alternative to autogenous bone transplantation.[4–6] In addition, materials that can be additively manufactured offer the advantage of being able to be individually dimensioned according to the defect. The growing demand requires bone replacement materials to possess improved mechanical and biological properties. An ideal biomaterial is characterised by biocompatibility and is replaced by regenerated new bone after the healing period. In terms of chemical composition and architecture, it should mimic the extracellular bone matrix so that cells can adhere, multiply and differentiate.[7, 8] Biomaterials that are very frequently used include ceramics such as beta-tricalcium phosphate (β-TCP) and hydroxyapatite (HA). Owing to their osteoconductivity and similar composition to that of bone, they play a crucial role in tissue engineering. In particular, β-TCP has a high degree

of solubility and is broken down more quickly, enabling replacement with new, regenerated bone.[9–11] Polymers such as poly-L-lactic acid (PLLA) or poly-D, L-lactic acid (PDLLA) have also shown promise in numerous studies. Their biocompatibility and biodegradability make them suitable for the regeneration of bone tissue. They have sufficient mechanical stability, and their modulus of elasticity is closer to that of the natural cortex than ceramic materials, which are more brittle.[12, 13] Composite scaffolds made of polymer and ceramic are also frequently used biomaterials in bone tissue engineering and are currently being investigated clinically. Ceramic and polymer components are combined to achieve good biocompatibility and stability.[14–19] Likewise, PDLLA or PLLA mixed with calcium carbonate (CC) or magnesium (Mg) is rated as promising.[20, 21] However, the comparability of materials has been limited by the different methodologies of the various studies on them, and most studies have only described one group of materials. Previous studies have shown that certain defined parameters, such as pore size, pore shape and porosity, in addition to certain defined mechanical properties and biocompatibility, are decisive for cell adhesion and bone ingrowth.[22, 23] Thanks to the 3D construction of a scaffold that is optimal with regard to these parameters, the bone metabolism can be positively influenced in a targeted manner. However, this complex construction can only be implemented with difficulty using conventional production techniques, since parameters such as pore size, porosity and pore distribution cannot be precisely controlled.[24] We examined such materials more closely, all of which can be additively manufactured in the clean room using standardised techniques. In this way, defined construction parameters can be implemented precisely for a wide variety of materials. We examined eight different biomaterials of PLLA–CC; PLLA–TCP; PLLA, polyglycolic acid and CC (PLLA–PGA–CC); PDLLA–Mg; PDLLA; β-TCP–HA; and β-TCP and β-TCP' for biocompatibility using the same methodology. The compounding of the materials, including special processing by 3D printing, represents an innovation in additive manufacturing. All eight materials were produced by digital light processing, selective laser sintering or fused deposition modelling (FDM). Both the respective processes and the pore structures were optimised accordingly in order to be able to produce comparable scaffolds using all technologies. This enabled us to objectively compare a wide range of materials and material combinations.

Material and methods

Biomaterials

The scaffolds were manufactured, packaged and then sterilised with gamma irradiation in cooperation with the medical technology company Karl Leibinger Medizintechnik under clean room conditions. All scaffolds were constructed with a diameter of 12 mm and a height of 5 mm (Fig. 1). In order to obtain comparable scaffolds, the wall was reduced in the first step. After an optimisation of the process parameters, sections of the wall were removed in a second optimisation, thus making the scaffolds permeable to liquids and cells in the edge structures. In a final step, the pore geometry was enlarged and rotated in order to achieve greater reproducibility and comparability between the various manufacturing methods (Figs. 2 & 3). The PLLA–CC scaffolds were manufactured on the FORMIGA P 110 (EOS), using selective laser sintering technology. The scaffolds made of PLLA–TCP, PLLA–PGA–CC, PDLLA–Mg and PDLLA were manufactured using FDM technology on the ARBURG AKF freeformer 200-3X (ARBURG). To achieve technical feasibility, technically pure Mg (99.8%, Alfa Aesar) was used. The β-TCP–HA and β-TCP scaffolds were manufactured using digital light processing technology on the

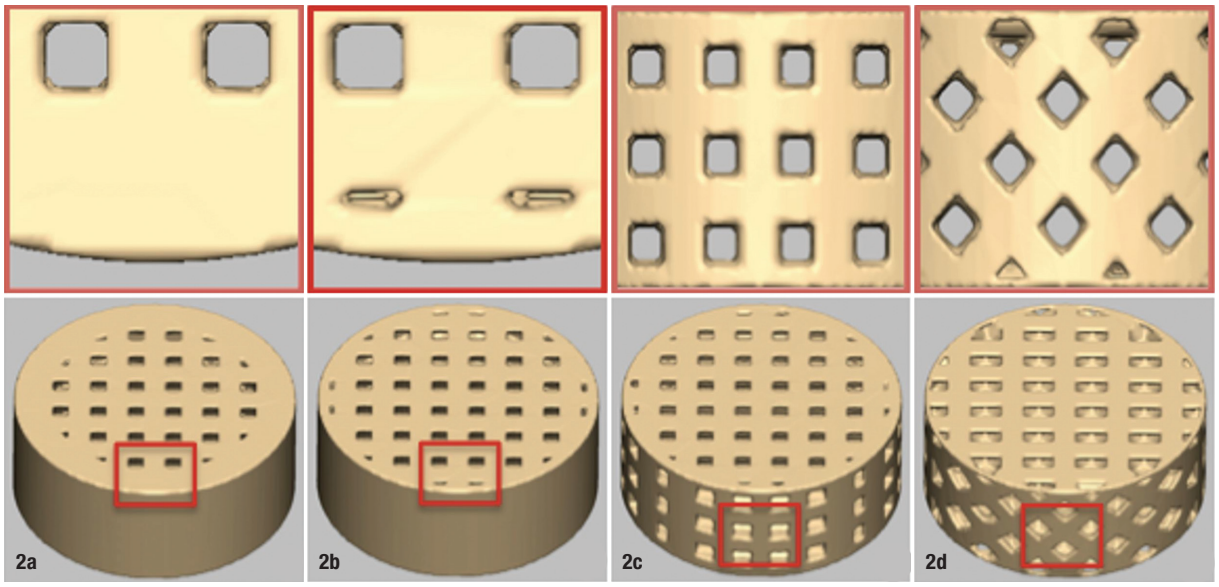

Fig. 2: Scaffold production. Initial state **(a)**, reduction of the wall **(b)**, removal of sections of the wall **(c)**, enlargement and rotation of the pore geometry **(d)**.

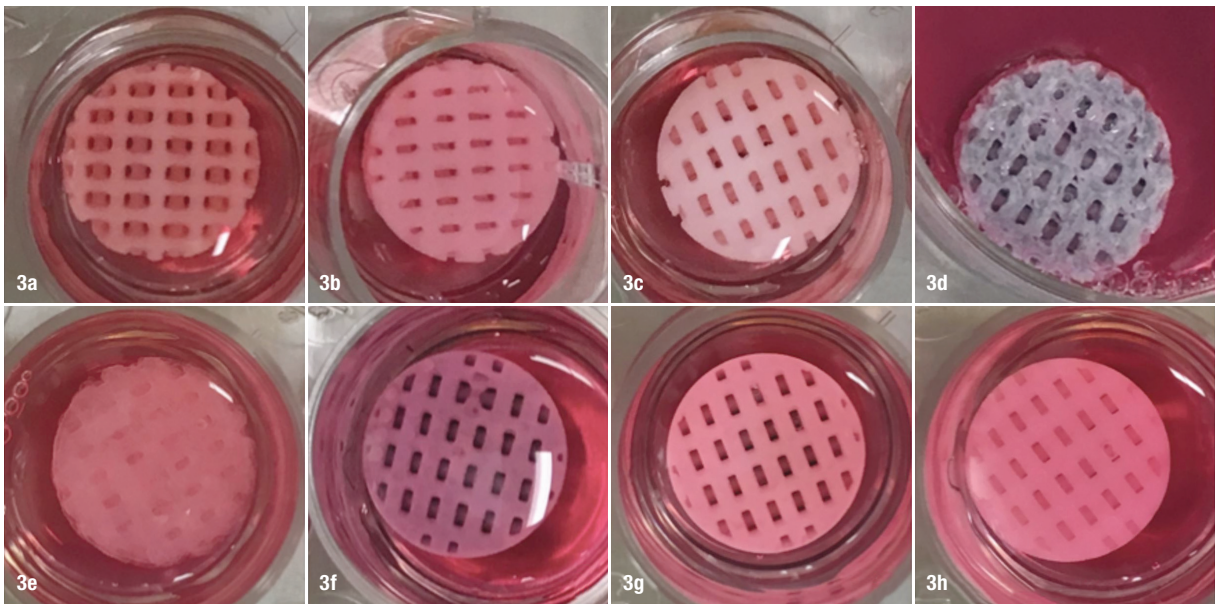

Fig. 3: Examined scaffolds in culture medium. Scale bar = 10 mm. PLLA-CC **(a)**, PLLA-TCP **(b)**, PLLA-PGA-CC **(c)**, PDLLA-Mg **(d)**, PDLLA **(e)**, β-TCP-HA **(f)**, β-TCP **(g)**, β-TCP' **(h)**.

CeraFab 7500 (Lithoz). For the β-TCP–HA scaffolds, sintering took place between 1,150 and 1,300 °C, and for the β-TCP between 1,050 and 1,200 °C. Two scaffold types with different mechanical properties were made from β-TCP (β-TCP and β-TCP'). To better differentiate between β-TCP and β-TCP', the flexural strength was determined in a flexural test of the samples. The flexural strength between β-TCP and β-TCP' increases with increasing sintering temperature. A flexural strength of 68 N/mm² was determined for β-TCP and of 120 N/mm² for β-TCP'.

Seeding of biomaterials and cultivation

The biomaterials were seeded with human osteoblasts (PromoCell). Before seeding, the scaffolds were incubated for 72 hours at 37 °C and 5% carbon dioxide (CO_2) in standard culture medium (Osteoblast Growth Medium, PromoCell) to hydrate the scaffold matrix in order to later facilitate the growth of the cells into the scaffold structure. In addition, the pores in the medium were de-aerated by applying a vacuum in a 100 ml syringe. The cells were amplified in monolayer culture with standard culture medium to a confluence of 80–90% and then passaged. Cells from the second passage were used. For seeding, the cells were detached by trypsinisation and resuspended in standard culture medium to obtain a cell suspension with a final cell concentration of 2×10^6 cells/ml. One scaffold was placed per well in a 24-well plate. For seeding, the cell suspension was pipetted on to the hydrated scaffolds. To ensure that the cells were homogeneously distributed, each batch was pipetted from a cell suspension and vortexed several times in between. For the apoptosis and proliferation assays, the scaffolds were seeded with 2×10^5 cells, each with a density of 3.54×10^5 cells/cm³. In order to enable cell adhesion, the seeded scaffolds were incubated for 30 minutes at 37 °C and 5% CO_2. The well was then filled with 1 ml of culture medium so that the scaffolds were covered by medium. During the course of this, the medium was changed every two days.

Fluorescence microscopy

In order to visually validate the success of culturing after 21 days, the scaffolds were evaluated using a fluorescence microscope. The scaffolds (n = 2) were seeded with ten million cells and cultured for 21 days in differentiation medium (StemMACS OsteoDiff Media, human, Miltenyi Biotec) and then fixed in 3% formaldehyde. They were covered in a 24-well plate with a Hoechst staining solution (Hoechst 33342, AppliChem, in phosphate-buffered saline; 1:2,000) and incubated for 10 minutes at room temperature, protected from light. They were then transferred to a well filled with phosphate-buffered saline and viewed there under a fluorescence microscope (BZ-9000 BIOREVO, Keyence) with a DAPI filter.

MTS assay

The number of metabolic cells growing on the scaffold surface and in the scaffold matrix was estimated using an MTS assay (CellTiter 96 AQ_{ueous} One Solution, Promega). This proliferation assay uses tetrazolium salt, which is converted by the cells into purple formazan. The amount of formazan dye produced is directly proportional to the number of proliferating cells in the sample. Since this assay is not cytotoxic, it is suitable for multiple measurements over long periods. To each scaffold, 200 µl of MTS assay was added in 1,000 µl of phenol-free medium and incubated for 1 hour at 37 °C and 5% CO_2. The absorption of each sample was then measured three times at 490 nm in a photometer (BioPhotometer plus, Eppendorf).

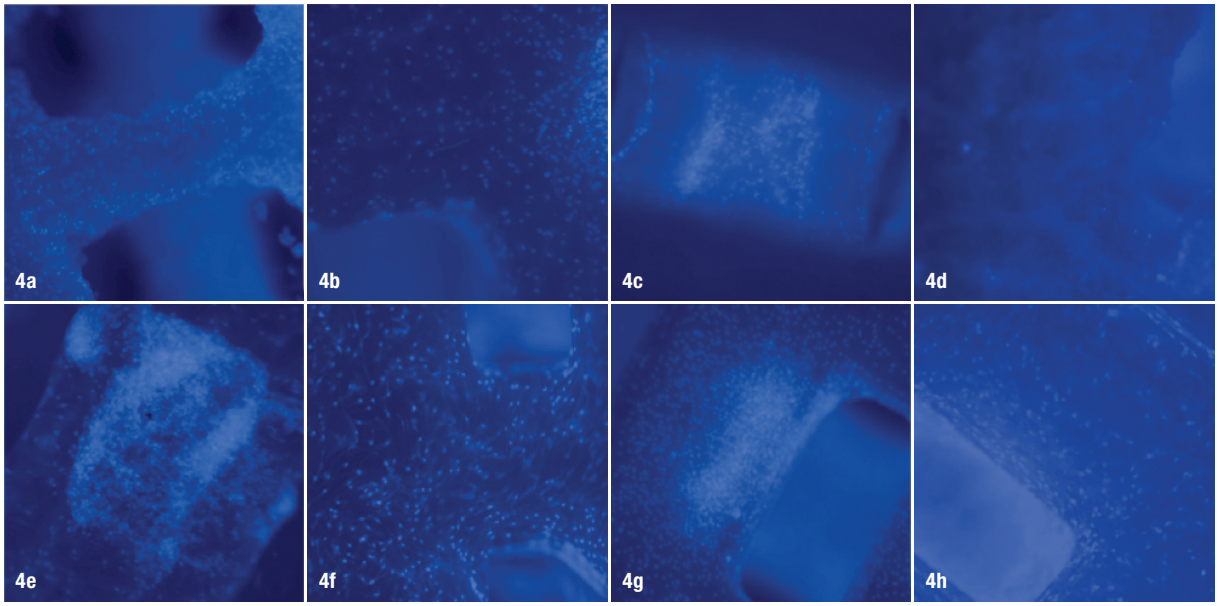

Fig. 4: Fluorescence microscopy of the scaffold surface with Hoechst staining solution on day 21 after seeding. Scale bar = 200 µm. PLLA-CC **(a)**, PLLA-TCP **(b)**, PLLA-PGA-CC **(c)**, PDLLA-Mg **(d)**, PDLLA **(e)**, β-TCP-HA **(f)**, β-TCP **(g)**, β-TCP' **(h)**.

An unseeded scaffold, medium and MTS served as control. To determine the number of cells, a calibration curve was carried out with human osteoblasts. The samples were analysed on days 2, 5, 7, 14 and 21 (n = 8).

Apoptosis assay

In order to assess the apoptosis activity of the cells on the scaffolds, an apoptosis assay (Caspase-Glo 3/7 assay, Promega) was carried out. A DEVD substrate was used which, in the presence of the apoptotic enzyme caspase -3 or -7, luciferase and adenosine triphosphate, results in the luciferase reaction and the production of light. This luminescence is directly proportional to the apoptosis activity of the cells. At room temperature, Caspase-Glo reagent was pipetted in a ratio of 1:1 on to the scaffolds in the medium. These were then agitated on the plate shaker (30 seconds, 300–500 rpm) and incubated at constant room temperature for 45 minutes. The luminescence of each sample was then measured three times in a plate-reading luminometer (Victor X2, PerkinElmer). The samples (n = 8) were analysed on days 2, 5, 7, 14 and 21. To determine the apoptosis activity based on the metabolic cells in the scaffold, the quotient of the apoptosis value (luminescence) divided by the cell count in the scaffold was generated. With the help of an establishment experiment, it was shown that the assay is not cytotoxic and is therefore suitable for a series of measurements over longer periods. For this purpose, the proliferation rate of cells incubated with the apoptosis assay was checked by means of the MTS assay.

Cytotoxicity assay

The cytotoxicity assay was performed according to ISO 10993-5. Extracts of the scaffolds were produced by hydrating them in 2 ml of serum-containing culture medium for 72 hours in order to accumulate potentially cytotoxic substances in the medium. Human osteoblasts were cultivated in 96 well plates with a density of 1,000 cells per well and, after addition of the extracts (in the dilutions 100%, 75%, 50% and 25%), incubated for 24 hours. Viability was assessed with the aid of the proliferation assay (CellTiter 96 AQ_{ueous} One Solution). The extract from ThinCert membranes (Greiner Bio-One), which are considered to be particularly cell-friendly, served as a negative control, and 100% dimethylsulfoxide (DMSO) was used as a positive control.

Sulforhodamine B assay

The sulforhodamine B assay allows conclusions to be drawn about the number of cells in the osteoblasts growing in the milieu of the scaffolds by measuring protein quantities. Human osteoblasts were seeded in six-well plates at a density of 100,000 cells per well. With the help of ThinCert inserts, the scaffolds were placed in the medium above the cells. It was thereby possible to investigate whether the materials release cytotoxic substances into the medium over longer periods and to what extent this affects the number of cells and therefore cell growth. The cells were fixed with methanol (99%; Carl Roth) on the measurement days and stored at –80 °C. For staining, the methanol was removed from the wells, and the cells were covered with sulforhodamine B staining solution (1% acetic acid solution and 0.4% w/v sulforhodamine B sodium salt, Sigma). Incubation was performed for 30 minutes at room temperature with continuous agitation. The sulforhodamine B staining solution was then removed, and the fixed cells were washed five times in a 1% acetic acid solution. The stained cells were dried and, after 24 hours,

dissolved in 2 ml of 10 mM Tris buffer. The absorption of each sample was then measured three times at 550 nm in a photometer (BioPhotometer plus). To determine the number of cells, a calibration curve was carried out with human osteoblasts. The samples (n = 8) were analysed on days 2, 5 and 7.

Statistical analysis

The data for the tests performed are presented as mean ± standard deviation. Statistical analysis was performed using GraphPad Prism 8 (GraphPad Software). To evaluate the differences between time points and groups, one-way ANOVA and Friedman Test were performed followed by Dunn's post hoc multiple comparisons. T-test and Mann–Whitney U test were performed for significance of viability in cytotoxicity testing. A P value < 0.05 was considered significant.

Results

Fluorescence microscopy

PLLA–PGA–CC, PDLLA, β-TCP–HA, β-TCP and β-TCP' showed the highest cell density (Fig. 4).

MTS assay

The initial cell count after seeding was 2×10^5 cells/scaffold. On day 2, the first measurement was performed. The cell count on day 21 was evaluated in comparison to days 2, 5, 7 and 14. In the group of PLLA-based polymers, the PLLA–CC scaffold contained 2.77 x 10^5 ($\pm$ 0.34×10^5) cells on day 2. After a slight decrease in cell count on day 5 ($2.01 \times 10^5 \pm 0.80 \times 10^5$) and day 14 ($2.36 \times 10^5 \pm 0.51 \times 10^5$), the cell count per scaffold increased to 4.20×10^5 ($\pm 0.63 \times 10^5$) after 21 days ($p < 0.05$). For PLLA–TCP, the cell count increased until day 7 ($8.28 \times 10^5 \pm 1.34 \times 10^5$), decreased to 3.17×10^5 ($\pm$ 0.93×10^5) on day 14 and increased to 4.49×10^5 ($\pm$ 1.03×10^5) on day 21. The difference in cell count between day 21 and day 14 was significant ($p < 0.05$). For PLLA–PGA–CC, the cell count increased from day 2 ($4.37 \times 10^5 \pm 0.56 \times 10^5$) to day 5 ($3.48 \times 10^5 \pm 1.16 \times 10^5$), day 14 ($4.07 \times 10^5 \pm 0.62 \times 10^5$) and day 21 ($5.74 \times 10^5 \pm 0.61 \times 10^5$; $p < 0.05$). Overall, the highest values were obtained on day 7 with 10.15×10^5 ($\pm$ 2.30×10^5) cells. PLLA–PGA–CC showed the highest cell counts over time in the group of PLLA-based polymers (Figs. 5a & d). For PDLLA–Mg, the total cell count decreased from 0.14×10^5 ($\pm$ 2.25×10^5) on day 2 to 0.00×10^5 ($\pm$ 0.26×10^5) on day 21, having only a temporary slight increase on day 5 ($1.44 \times 10^5 \pm 0.88 \times 10^5$) and day 14 ($0.89 \times 10^5 \pm 0.66 \times 10^5$). PDLLA increased steadily from day 2 ($1.67 \times 10^5 \pm 0.44 \times 10^5$) to day 5 ($2.65 \times 10^5 \pm 0.71 \times 10^5$), day 7 ($4.19 \times 10^5 \pm 1.00 \times 10^5$), day 14 ($4.13 \times 10^5 \pm 1.31 \times 10^5$) and day 21 ($9.39 \times 10^5 \pm 1.12 \times 10^5$; each $p < 0.05$). In the group of PDLLA-based polymers, PDLLA showed the best results over time (Figs. 5b & e). For the ceramics, an increase in cell count was observed in β-TCP–HA on day 21 to 6.54×10^5 ($\pm$ 1.26×10^5) compared with day 2 ($3.34 \times 10^5 \pm 0.68 \times 10^5$), day 5 ($3.22 \times 10^5 \pm 1.05 \times 10^5$) and day 14 ($4.83 \times 10^5 \pm 1.01 \times 10^5$; $p < 0.05$ for days 2 and 5). β-TCP increased steadily from day 2 ($1.67 \times 10^5 \pm 0.80 \times 10^5$) to day 5 ($3.93 \times 10^5 \pm 1.75 \times 10^5$), day 7 ($5.74 \times 10^5 \pm 1.49 \times 10^5$), day 14 ($5.68 \times 10^5 \pm 1.70 \times 10^5$) and day 21 ($7.35 \times 10^5 \pm 1.43 \times 10^5$; $p < 0.05$ for days 2 and 5). β-TCP' also showed a significant increase in cell count on day 21 ($7.46 \times 10^5 \pm 4.07 \times 10^5$) compared with day 2 ($1.87 \times 10^5 \pm 1.41 \times 10^5$), day 5 ($5.01 \times 10^5 \pm 2.55 \times 10^5$) and day 7 ($4.53 \times 10^5 \pm 2.62 \times 10^5$; $p < 0.05$). Day 14 showed the highest value with 8.26×10^5 ($\pm$ 2.98×10^5) cells (Figs. 5c & f). In summary, β-TCP–HA, β-TCP and β-TCP' showed the best results over time, and PDLLA–Mg showed the lowest cell counts.

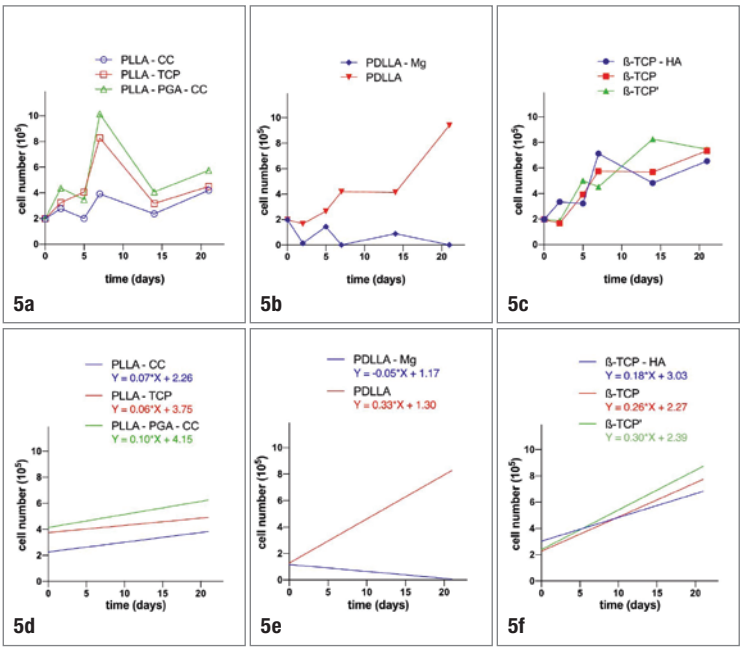

Fig. 5: Proliferation assay (MTS assay). Determination of the number of proliferating cells in the scaffolds after two, five, seven, 14 and 21 days **(a–f)**. Regression lines to determine growth tendency over time **(d–f)**.

Apoptosis assay

In order to determine the apoptosis activity in relation to metabolic cells, the quotient of the apoptosis value (luminescence) divided by the cell count in the scaffold was generated. The PLLA-based polymers all showed a similar course of apoptosis activity over the observation period. For PLLA–CC, apoptosis activity was significantly increased on day 2 to 118.57×10^{-5} ($\pm$ 19.60×10^{-5}) compared with days 5, 7, 14 and 21, when the value approached zero (range: 0.00–5.29×10^{-5}; $p < 0.05$). PLLA–TCP, with a value of 187.19×10^{-5} ($\pm$ 32.20×10^{-5}), and PLLA–PGA–CC, with a value of 107.32×10^{-5} ($\pm$ 21.90×10^{-5}), also showed increased apoptosis activity on day 2 compared with the other days ($p < 0.05$; Figs. 6a & d). After initially increased apoptosis on day 2 ($84.15 \times 10^{-5} \pm 53.80 \times 10^{-5}$), PDLLA–Mg decreased to 1.44×10^{-5} ($\pm$ 2.50×10^{-5}) on day 5 and increased again on day 7 ($971.03 \times 10^{-5} \pm 1{,}358.90 \times 10^{-5}$; $p < 0.05$). Subsequently, it remained slightly elevated at

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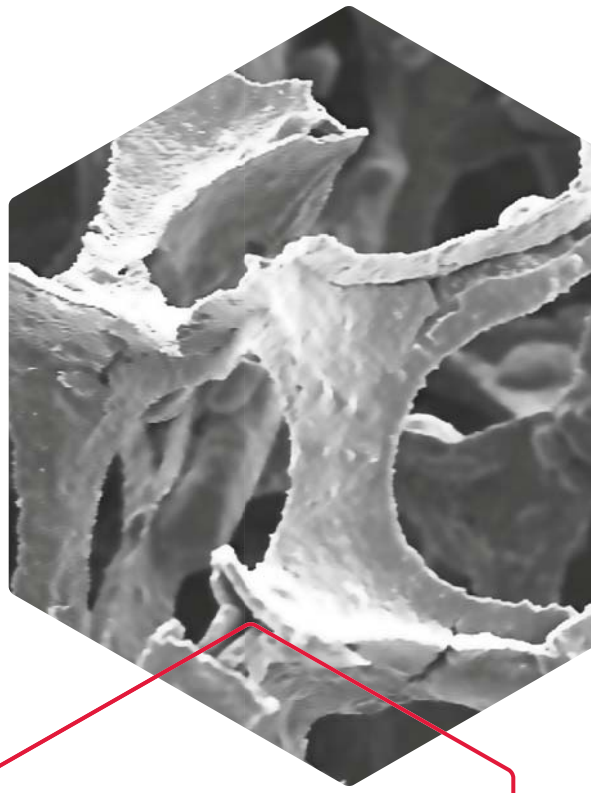

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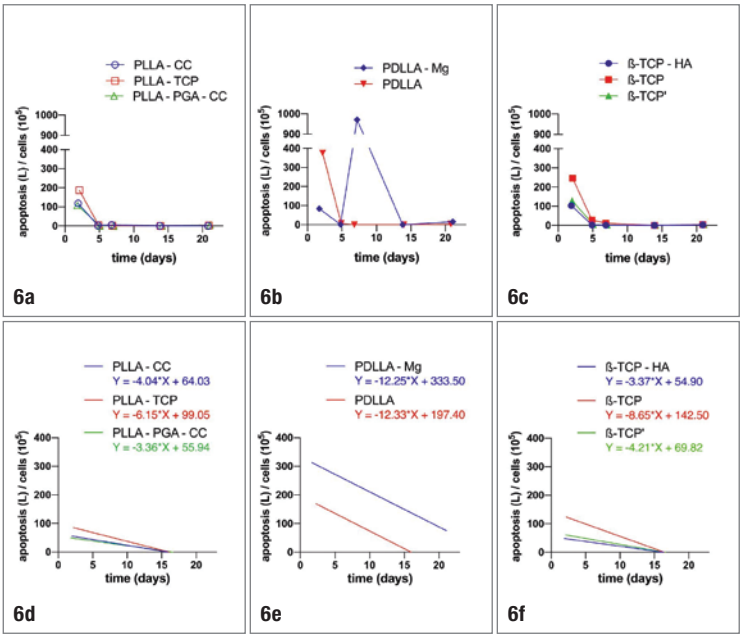

Fig. 6: Apoptosis assay. L = luminescence. Determination of apoptosis activity related to cell count on the scaffolds after two, five, seven, 14 and 21 days **(a–f)**. Regression lines to determine apoptosis tendency over time **(d–f)**.

15.40×10^{-5} (± 9.50×10^{-5}) on day 21 ($p < 0.05$ compared with day 5). For PDLLA, apoptosis activity was significantly increased only on day 2 ($375.48 \times 10^{-5} \pm 25.60 \times 10^{-5}$) and then decreased to low values between 0.00 and 7.01×10^{-5} (Figs. 6b & e). All ceramics showed a similar course of apoptosis activity. On day 2, β-TCP–HA, with a value of 103.52×10^{-5} (± 32.50×10^{-5}), and β-TCP', with a value of 129.85×10^{-5} (± 30.50×10^{-5}), showed significantly increased apoptosis activity compared with days 5, 7, 14 and 21 (0.00–4.79×10^{-5}). Also, β-TCP showed an increased value on day 2 ($246.27 \times 10^{-5} \pm 34.90 \times 10^{-5}$; $p < 0.05$). Furthermore, the curve flattened more slowly here (Figs. 6c & f). In summary, apoptosis decreased towards zero after having initially increased on day 2 for PLLA-based polymers, ceramics and PDLLA. For PDLLA–Mg, apoptosis activity peaked again on day 7 and moderately increased again after 21 days.

Cytotoxicity assay

The proliferation of human osteoblasts was not affected by the extracts (100% undiluted extract) of the biomaterials (Fig. 7). Cell growth and metabolism were unchanged compared with the non-cytotoxic control (negative control). The negative control value was set to 100%. The viability of extracts of PLLA–CC (156%) and β-TCP (151%) even exceeded that of the negative control. Cells incubated in 100% DMSO (positive cytotoxic control) reflected the cytotoxic effect of DMSO on viability (5.6 ± 4.8%). The viability of human osteoblasts cultured in DMSO was significantly reduced compared with the negative control and the scaffold extracts ($p < 0.05$). According to ISO guidelines, cell viability in the range of 0 to 50% reflects a strong cytotoxic effect of the tested extract, whereas values between 70 and 100% reflect the absence of cytotoxic components. The viability of 50% extract dilutions was at least as high as that of 100% extracts for all biomaterials, as required by the ISO guidelines.

Sulforhodamine B assay

The initial cell count after seeding was 1×10^5 cells/scaffold. On day 2, the first measurement was performed. After an increase of the cell count of PLLA–CC on day 2 to 4.46×10^5 (± 1.90×10^5), it decreased on day 5 ($2.57 \times 10^5 \pm 1.60 \times 10^5$) and remained almost unchanged on day 7 ($2.76 \times 10^5 \pm 1.01 \times 10^5$). For PLLA–TCP, the cell count after day 2 ($4.36 \times 10^5 \pm 2.63 \times 10^5$) decreased to 3.18×10^5 (± 0.97×10^5) on day 5 and to 2.79×10^5 (± 1.49×10^5) on day 7. PLLA–PGA–CC showed almost constant cell counts, having a value of 2.38×10^5 (± 0.74×10^5) on day 2 and of 2.20×10^5 (± 0.95×10^5) on day 5. On day 7, there was a significant increase to 2.84×10^5 (± 0.79×10^5) compared with day 5 ($p < 0.05$; Figs. 8a & d). Starting with 3.56×10^5 (± 0.66×10^5) on day 2, the cell count of PDLLA–Mg dropped to 1.45×10^5 (± 0.44×10^5) on day 5 and remained nearly unchanged ($1.52 \times 10^5 \pm 0.55 \times 10^5$) on day 7. For PDLLA, a value of 2.61×10^5 (± 0.23×10^5) was observed on day 2. On day 5, the cell count slightly decreased ($2.06 \times 10^5 \pm 0.49 \times 10^5$), and it also remained nearly unchanged on day 7 ($2.11 \times 10^5 \pm 0.39 \times 10^5$; Figs. 8b & e). After day 2 with a cell count of 2.22×10^5 (± 0.37×10^5), β-TCP–HA showed a slight decrease in cell count on day 5 ($1.84 \times 10^5 \pm 0.37 \times 10^5$). The count increased slightly on day 7 ($2.21 \times 10^5 \pm 0.52 \times 10^5$). β-TCP' showed a similar course, having 3.01×10^5 (± 1.82×10^5) cells on day 2, a slight decrease on day 5 ($2.64 \times 10^5 \pm 0.72 \times 10^5$) and an increase on day 7 ($3.08 \times 10^5 \pm 0.44 \times 10^5$) compared with day 5 ($p < 0.05$). β-TCP had a cell count of 2.37×10^5 (± 0.52×10^5) on day 2, a minimal decrease on day 5 ($2.08 \times 10^5 \pm 0.47 \times 10^5$) and a significant increase on day 7 ($6.72 \times 10^5 \pm 5.88 \times 10^5$) compared with day 5 ($p < 0.05$; Figs. 8c & f). PLLA–PGA–CC, β-TCP and β-TCP' showed a significant increase in cell count as well as the largest slope of the regression line over the observation period (Figs. 8d & f). The other materials showed only insignificant changes or decreasing cell count.

Discussion

Despite promising advances in tissue engineering, the treatment of large bone defects is still a challenge.[25] An optimal biomaterial should be biocompatible and have controllable biodegradability and architecture and optimal mechanical properties.[26] An interconnected pore system, porosity and optimal pore size are required, although opinions differ on this.[27, 28] In general, however, a pore size of over 300 µm is favoured.[29] We chose a pore diameter of 800 µm to allow osteogenesis, fluid exchange and subsequent vascularisation. While a complex scaffold design is difficult to implement using conventional

techniques, additive manufacturing processes allow for individual implant production.[24, 30, 31] This enables us to both individually adapt the scaffold shape to a bone defect and to construct the microscopic scaffold architecture. We evaluated the biocompatibility of various additively manufactured biomaterials using a proliferation, apoptosis, cytotoxicity and sulforhodamine B assay and were thereby able to objectively evaluate and compare a wide variety of materials and material groups. In the proliferation and apoptosis assays, multiple measurements could be made over longer periods owing to the lack of cytotoxicity of the assays. This also has the advantage of better comparability and fewer inaccuracies. TCP–HA is becoming an increasingly important biomaterial in bone tissue engineering. Owing to its similarity to the mineral phase of bone, HA plays an important role in cell adhesion and proliferation and, along with tricalcium phosphate, is one of the most frequently used ceramics.[32–34] *In vivo* studies have also shown that the combination of TCP–HA induces bone formation.[35–37] In this study, β-TCP–HA showed a significant increase in the number of cells growing on the scaffold over 21 days, but the cell count on days 14 and 21 was lower than that of β-TCP and β-TCP'. The apoptosis activity of β-TCP–HA was significantly increased on day 2 compared with the other days; over time, it decreased to zero. Initially increased apoptosis activity was observed in all the materials and is most likely explained by the trypsinisation and the passage when seeding the scaffolds. After day 2, hardly any cells were in apoptosis, evidence of the cell compatibility of the scaffold. Compared with pure β-TCP, the quotient of the apoptosis value divided by the cell count was significantly lower for the TCP–HA on day 2. Woo et al. describe suppressed cell apoptosis through the addition of HA to composite scaffolds.[38] This is in line with our results. In the cytotoxicity test in accordance with ISO 10993-5, the growth of the osteoblasts was not impaired by the scaffold extract either. The sulforhodamine B assay evaluated the number of osteoblasts that grew in the scaffold extract in the immediate vicinity of the scaffold for seven days. Good results were demonstrated here; the regression line had a positive gradient. However, the total number of cells was even higher for pure β-TCP and β-TCP'. Despite very good biocompatibility and low apoptosis values, TCP–HA showed somewhat poorer results than β-TCP and β-TCP' with regard to cell proliferation and growth behaviour. β-TCP is one of the most used biomaterials. Its osteoconductivity, rapid degradability and similarity to the composition of bone make it suitable for bone tissue engineering.[10, 11] This has also been shown by numerous *in vivo* studies. For example, Kondo et al. successfully implanted β-TCP into femur bones in the rat model.[39] The brittleness of the material usually makes it difficult to adapt to the individual,[40] but this is no longer necessary owing to the possibility of individual construction using additive manufacturing processes. Since, depending on the dimensions, classic fixation of ceramics with screws is not possible, alternative fixation techniques are necessary (e.g. a cage). Both β-TCP and the mechanically improved β-TCP' with higher flexural strength showed a significant increase in cell count from day 2 to day 21. In addition, both (with PDLLA) achieved the highest cell counts on days 14 and 21 compared with all other materials and therefore better cell proliferation. While β-TCP' showed a twofold drop in cells during the process, the growth curve of β-TCP demonstrated a consistent upward trend. After initially elevated values (day 2) for β-TCP and β-TCP', apoptosis activity decreased towards zero. On day 2, the quotient of the apoptosis value divided by the cell count of β-TCP was significantly increased compared with β-TCP' and TCP–HA. This agrees with the results of the proliferation assay, in which β-TCP had the lowest cell count among the ceramics on days 2 and 5, as the cells increasingly went into programmed cell death. However, the number of cells then rose steadily to very good values. Osteoblast proliferation was not negatively influenced in the cytotoxicity assay by the extract of β-TCP or β-TCP', also indicating good biocompatibility. In the sulforhodamine B assay, we observed a higher cell count on day 7 for β-TCP and β-TCP' compared with TCP–HA; for β-TCP', this difference was significant. Compared with all the materials, they also showed the best results here, having a regression line gradient of 67.5 (β-TCP) and 23.2 (β-TCP'). With regard to cell proliferation and growth behaviour, β-TCP and β-TCP' showed the best results in the ceramic scaffolds group. PLLA–CC was recently described in the literature as a bone replacement material.[20] CC has a beneficial effect in bone

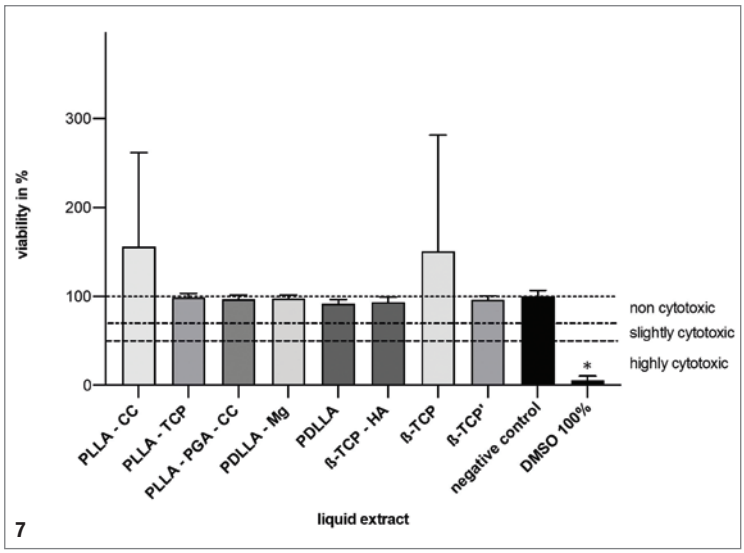

Fig. 7: *In vitro* cytotoxicity of 100% undiluted extract. Human osteoblasts cultivated in control extract (negative control = dotted line, 100%) or undiluted scaffold extract all showed high viability. The viability of osteoblasts cultivated in dimethylsulfoxide (positive cytotoxic control) was significantly reduced compared with the scaffold extracts ($p < 0.05$).

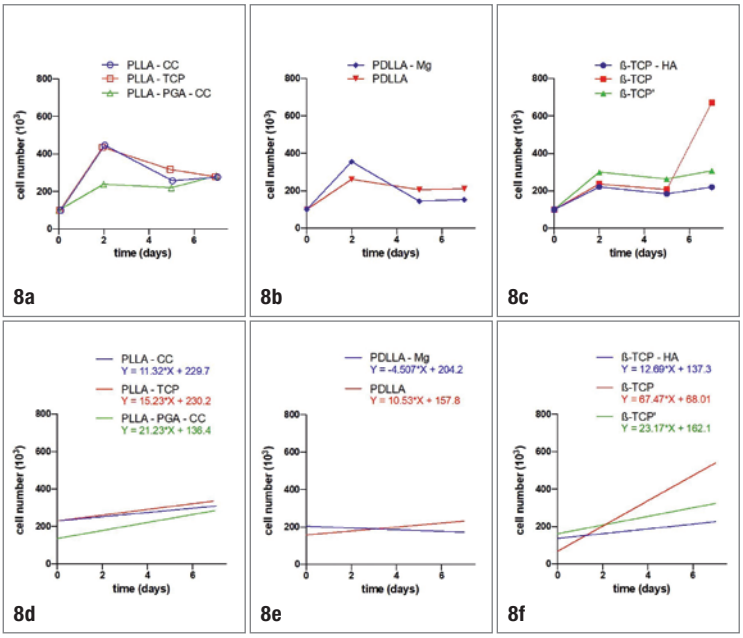

Fig. 8: Sulforhodamine B assay. Determination of the cell count of osteoblasts growing in the scaffold environment after two, five and seven days **(a–f)**. Regression lines to determine growth tendency over time **(d–f)**.

tissue engineering, as extracellular calcium enhances osteogenic gene expression and promotes bone regeneration.[41] CC was mentioned earlier as a suitable filler for polyester, because its pH-stabilising effect buffers the acidic degradation of polylactides.[42] In this study, PLLA–CC showed a significant increase in cells growing in the scaffold from day 2 to day 21, but the cell count was slightly lower than that of the other PLLA-based scaffolds at all measurement times. Apoptosis activity was significantly increased initially (day 2) and decreased towards zero over time, indicating the long-term cell tolerance of the scaffold. The increased apoptosis activity is probably related to differences in the degradation kinetics and initial water absorption of the polymeric scaffold systems. Different proteins also play a role as deposits on the scaffolds. In the cytotoxicity test, the growth of the osteoblasts was not impaired by the scaffold extract either. In the sulforhodamine B assay, the cell count on day 7 was not significantly different from that of the other PLLA scaffolds. However, the curve showed the smallest regression line gradient among the PLLA scaffolds. Gayer et al. described good cell compatibility of PLLA–CC, but there is no possibility of comparison with other materials.[20] In this study, PLLA–CC demonstrated overall good biocompatibility. In comparison with the poly-L-lactides PLLA–TCP and PLLA–PGA–CC, however, the latter can be assessed as even more promising in terms of cell proliferation and growth behaviour. Composite scaffolds made from PLLA–TCP are frequently used biomaterials in bone tissue engineering.[14–18] The aim is to overcome the shortcomings of the individual materials by combining PLLA and TCP. On the one hand, TCP counteracts the acidic environment that results from the breakdown of polylactide. On the other hand, the combination of PLLA and TCP improves the mechanical properties of a scaffold.[32, 43] We observed a non-significant increase in cells growing in the scaffold from day 2 to day 21; the increase from day 14 to day 21 was significant. The cell count over time was higher than for PLLA–CC, but lower than for PLLA–PGA–CC. For PLLA–TCP, the apoptosis activity was significantly increased on day 2, and over time, it also decreased to zero. The results in the cytotoxicity test reflected the absence of cytotoxic components. In the sulforhodamine B assay, the cell count on day 7 was not significantly different from that of the other PLLA scaffolds. However, the cell counts fell again after an increase on day 2, and the regression line showed a slightly lower gradient than PLLA–PGA–CC did. PLLA–PGA–CC in this composition has not yet been described in the literature as a bone replacement material. PLLA is already widely used in tissue engineering for the regeneration of bone tissue.[44–47] PGA is a less hydrophobic polymer with a relatively rapid degradation rate.[48] The co-polymer PLLA–PGA has been described for bioresorbable bone fixation in the form of screws, plates or orbital floor reconstruction plates.[49–52] There is also information on the good biocompatibility of the composite of poly (lactic-co-glycolic) acid (PLGA) and CC, but not on PGA–CC or PLLA–PGA–CC.[53] As a co-polymer of PGA, PLGA has similar properties in some cases. In our investigations, PLLA–PGA–CC showed a significant increase in cell metabolism from day 2 to day 21. The cell count of the osteoblasts growing on the scaffold was significantly increased on all measurement days compared with the other PLLA-based scaffolds, with the exception of PLLA–TCP on days 5 and 7. After initially increased values (day 2), the apoptosis activity decreased over time to zero, which is desirable. Furthermore, PLLA–PGA–CC sometimes showed the lowest quotient of the apoptosis value divided by the cell count compared with all the other materials, indicating good cell compatibility. In the cytotoxicity test too, the scaffold extract did not impair the growth of the osteoblasts. When evaluating the cell count in the sulforhodamine B assay, the cell count on day 7 was about the same as for the other PLLA scaffolds. However, PLLA–PGA–CC was the only material here that showed a significant increase in cell count over the course of the experiment and the largest gradient of the regression line. With regard to cell proliferation, growth behaviour and apoptosis activity, PLLA–PGA–CC showed the best results in the group of poly-L-lactides. PDLLA–Mg in this composition and Mg in this processing method have not yet been described in the literature. Mg is believed to have great potential in bone tissue engineering because of its biodegradability and its ability to promote new bone formation. In addition, the modulus of elasticity of Mg is comparable to that of cortical bone.[54–58] The problem, however, is the rapid corrosion of Mg, which can lead to a loss of structure and the release of degradation products.[59] The rate

of degradation of technically pure Mg is much faster than that of alloys such as WE34 which are already in clinical use. Because the degradation rates are significantly lower, these alloys also show very good biocompatibility, but other elements are also present here, for example rare earth elements that are not found in technically pure Mg. Our intention was to generate a polymeric matrix around the Mg material to create a polymer–metal composite to reduce the degradation rate of metallic Mg and thereby improve biological effects such as cell compatibility. Our results showed a comparatively low number of cells on the scaffolds. This was also confirmed by our electron microscopic examinations on day 21 (ongoing study). The quotient of the apoptosis value divided by the cell count was significantly increased in particular on day 7 compared with the other materials. The high value can be explained by the low cell count on the scaffold, and of these few cells, a large percentage were found to be in apoptosis. The high apoptosis levels are consistent with the low cell counts. In the sulforhodamine B assay too, the cell count was lower than that of the other materials, and the regression line decreased with a slope of –4.5. In contrast to this, osteoblast proliferation was not negatively influenced by the extracts, suggesting low cytotoxicity. Tavares et al. reported a lack of cytotoxicity of composite scaffolds to which Mg was added in the cytotoxicity test in accordance with ISO 10993.[60] This illustrates how important it is to test the material itself and not only to test an eluate produced from it, as here the effects of the scaffold architecture and other interactions are neglected. PDLLA–Mg showed less favourable results in this study compared with the other PDLLA-based materials. When looking at all the materials together, the other materials also performed better. This is presumably primarily due to the release of degradation products[59] and gas formation and was to be expected for pure Mg. It can be assumed that the slowdown in degradation, which we wanted to achieve with the composite material formulation, had occurred to an insufficient degree. However, we were able to show that the additive production of Mg-based implants using FDM technology is technically feasible. Further work is necessary to develop other material formulations that allow optimal degradation kinetics of technically pure Mg with a cell biologically compatible release of degradation products in order to fully exploit the material's potential for bone tissue engineering. PDLLA has been frequently described as a biomaterial.[42, 61–63] In this study, the cell count of the osteoblasts growing on the scaffold increased steadily up to day 21 and was significantly higher than that of the other PDLLA-based scaffolds on days 5, 7, 14 and 21. After initially strongly increased values (day 2), apoptosis activity decreased towards zero over the course of the experiment. In the cytotoxicity test too, the growth of the osteoblasts was not impaired by the scaffold extracts. In the evaluation of the cell count in the sulforhodamine B assay, the cell count on days 5 and 7 was significantly increased compared with PDLLA–Mg. In addition, PDLLA showed the most significant regression line gradient within the poly-D, L-lactide materials. With regard to cell proliferation, growth behaviour and apoptosis activity, PDLLA showed the best results in the group of poly-D, L-lactides. We evaluated the biocompatibility of the various additively manufactured biomaterials in the clean room and therefore had the opportunity to objectively evaluate and compare the different materials. The novelty of the materials is the compounding of these, including the special processing by 3D printing, to produce comparable scaffolds. Looking at all the materials together, the ceramic-based scaffolds proved to be the most promising. They showed the highest cell counts in the proliferation assay. They can be considered non-cytotoxic when used *in vitro*, and the apoptosis activity strongly decreased over the measurement period. β-TCP and β-TCP' exhibited particularly good results, showing the steepest growth curves in the sulforhodamine B assay. Among the poly-L-lactides, PLLA–PGA–CC performed best in terms of cell proliferation, growth behaviour and apoptosis activity. In the poly-D, L-lactide group, PDLLA showed the best results. The comparatively lowest cell counts and highest apoptosis values were observed for PDLLA–Mg. Further studies to improve the materials are planned, as these materials also demonstrated very promising properties that should be used for tissue engineering. A study is currently being carried out with regard to the behaviour of the materials *in vivo*.

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References

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Revolutionising implant dentistry

The Penguin II ISQ device as an example of progress

In the ever-evolving landscape of modern dentistry, technology continues to reshape the way professionals approach their craft. Among the many groundbreaking innovations in recent years, the Penguin II implant stability quotient (ISQ) device from Integration Diagnostics Sweden stands as a shining example of progress. This remarkable device is redefining implant dentistry and enhancing patient outcomes like never before.

A vision of accessibility and simplicity

Founded in 2015, Integration Diagnostics Sweden embarked on a mission to simplify the complexities of implant dentistry. The company recognised the need for an accessible and user-friendly ISQ measuring system that could benefit all dental practitioners working with implants. In November 2018, the company solidified its commitment to excellence by becoming part of the world-leading NSK Nakanishi group.

The power of resonance frequency analysis

At the heart of the Penguin II's success lies its utilisation of resonance frequency analysis. This technique involves exciting a MulTipeg attached to an implant and measuring its vibration frequency as an ISQ value. This value serves as an invaluable indicator of implant stability, reflecting factors such as bone quality and osseointegration. By providing a reliable ISQ value on a scale from 1 to 99, the Penguin II equips dental professionals with unprecedented precision.

Removing doubt, enhancing precision

One of the most notable features of the Penguin II is its ability to eliminate doubt from the implant dentistry process. Dentists can now assess osseointegration with unparalleled accuracy, enabling them to make informed decisions regarding the timing of implant loading. This capability is especially vital in a landscape where the trend is towards a minimal or no healing phase before implant loading. With the Penguin II, practitioners can confidently measure implant stability, ultimately improving the likelihood of successful patient outcomes.

Empowering dentists with data-driven decisions

The ISQ scale provided by the Penguin II serves as a powerful tool for dentists, offering objective values at various stages of osseointegration. This enables surgeons and restorative dentists to plan and execute implant procedures with heightened confidence and predictability. By ensuring better primary stability through precise ISQ measurements, the Penguin II plays a significant role in

reducing the risk of implant failure—a concern that weighs heavily on both clinicians and patients.

A trusted companion in dental clinics

Dr Adel Fani, a seasoned dental surgeon, has been using the Penguin ISQ device since 2017, and it has become a standard method for measuring implant stability in his clinic. Dr Fani conducts measurements both at the time of implant placement and before the final restoration. For challenging cases involving longer healing periods, unpredictable osseointegration or poor bone quality, he relies on the Penguin ISQ data, combined with radiographs and other modalities, to arrive at an objective diagnosis for his patients.

Dr Fani highlights the convenience of the reusable MulTi-pegs, which make planning implant procedures more efficient and cost-effective. The introduction of the Penguin II has further streamlined his workflow thanks to features like the new charging station, which also functions as a tabletop stand, and easily replaceable batteries.

In conclusion, the Penguin II ISQ device is not just a dental device; it represents a transformative shift in implant dentistry. Integration Diagnostics Sweden has developed a tool that empowers dental professionals to achieve exceptional results and enhance patient satisfaction. As we move forward, the Penguin II's impact on the world of implant dentistry will undoubtedly continue to grow, ushering in a new era of precision and confidence in dental care.

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Product information

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Dr Georg Bach, Germany

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"Implantology is teamwork—no ifs and buts!"—this was the opening statement by Dr Georg Bach, President of the German Association of Dental Implantology (DGZI), at the 52nd International Annual Congress, which took place in Hamburg on 6 and 7 October. What was true at the beginning of oral implantology in the late 1960s/early 1970s is just as valid today—if not more so. Reason enough for the DGZI, as the oldest European specialist society, to place this year's congress under the motto "Team": while the first day of the congress focused on 25 table clinics and two surgical tutorials, Saturday was entirely dedicated to science: 50 renowned speakers delivered outstanding scientific presentations to over 350 participants. The annual congress was completed by the oral hygiene day and seminars for practice teams as well as by a large adjoining dental exhibition featuring a three-dozen selected, "hand-picked" industry partners.

Future podium/young generation DGZI

A first highlight was offered to the participants at the very beginning of the congress with two remarkable lectures with completely different directions, but which together drew a clear picture of the future options of implantology, even of dentistry as a complete discipline. Just a few years ago, AI was not yet a topic in dentistry—this has completely changed at a rapid pace. Therefore, Prof. Dr Falk Schwendicke set the bar high right at the start of the congress with his presentation "Artificial intelligence in dentistry—benefits for the entire team?". As a leading specialist in AI in dentistry, Prof. Schwendicke stated that the prerequisites for AI are based on the availability of digital data and the development of new algorithms. Dentistry, however, is one of the difficult sectors for AI: on the one hand, due to the smaller amount of digital data compared to other fields and, on the other hand, due to the complexity of the matter, which requires many experts. Schwendicke sees major areas of application for AI in dental radiology (caries identification/recognition of anatomical structures, etc.) and in periodontology (e.g. periodontal staging). Schwendicke concluded his lecture with a glimpse into the future: based on an increase in the availability of digital data by a factor of 23 in the last ten years ("data explosion"), everyday data will therefore also gradually be used for medical AI applications, which will be beneficial for personalised medicine.

The Swiss speaker duo Dr Malin Strasding and MDT Vincent Fehmer, who presented "Collaboration 2.0—a concept for success in everyday practice and laboratory work", fully lived up to the congress motto. They introduced the Geneva concept—starting with digital diagnostics and digital treatment planning, followed by digital implantation and digitally supported dental technology. The crucial advantage of digital treatment planning is the predictable result for both, the patient and the dentist.

The intensity of the subsequent panel discussion and the number of questions posed by congress participants confirmed that the three speakers were exactly the right choice for this podium.

OP tutorials

It is already a tradition at DGZI congresses to present certain topics in more detail using animated images: a broadcast of surgical tutorials enabled congress participants and DGZI members to experience a unique insight into the work of renowned colleagues—and all in HD quality!

The event kicked off with a spectacular start given by Dr Dr Markus Schlee, who spoke on the topic "Update augmentation—is autologous bone still the gold standard?". From the very first minute of Schlee's presentation, it was obvious that this topic is also his main discipline. During his lecture, the Forchheim-based periodontist and implantologist discussed numerous patient cases. The speaker's conclusion: "Autologous bone has never been the gold standard, but today we do have material alternatives!"

In the second surgery tutorial, Dr Paul Schuh and MDT Bastian Wagner presented their reflections on "Digital disruption. Planning—surgery—restoration—is everything digitally possible?". Again, a clear credo: "Communication between dentists and dental technicians is of crucial importance for the success of treatment." The speaker duo presented their jointly developed concept for synoptic patient care and ultimately fully agreed with the statements of the previous speakers: "Implantology is teamwork—and the interface between dental technology and dentistry is extremely significant here!"

DGZI Implant Dentistry Awards in three categories

The DGZI Implant Dentistry Award, which went this year to Dr Diana Heimes from Mainz for her work on a vestibuloplasty using a collagen membrane, was embedded in the two surgical tutorials. Second place stayed in the Hanseatic city of Hamburg and went to Dipl.-Ing. Sandra Fuest from the research group led by Prof. Dr Dr Ralf Smeets. Alongside the congress theme, the DGZI also presented for the first time a team award, which went to the Schoebel and Reuleke dental practice in Hanover.

Table clinics

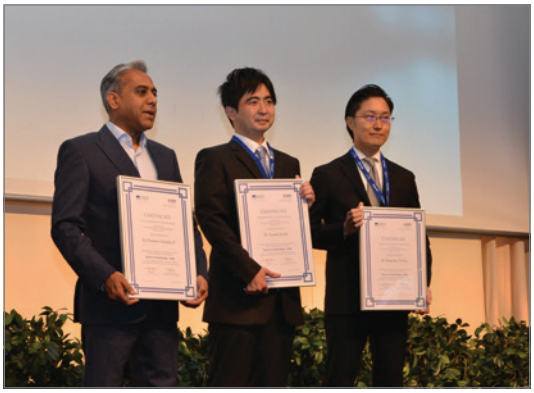
The table clinics were set up as round tables in the style of banquet seating instead of the usual parliamentary seating facing the stage and were an unusual view for some congress participants. At these tables, demonstrations on a wide variety of special implantology topics took place in three stages. Each exhibiting company had been provided with a table and engaged speakers to provide the demonstrations. The discussions and exchanges that took place immediately after the demonstrations proved to be very informative and the format was once again very well received by both congress participants and industry partners.

Second congress day—the "science day"

While the first day of the congress had a strong practical orientation, the following day focused on the scientific aspects. Based on a review of current trends, the focus here was also increasingly on the question: "How will implantology of the future be?"

The Saturday programme thus offered scientific overview lectures on all relevant areas of oral implantology, such as digital implantology and prosthetics, bone and tissue as well as materials and design.

The DGZI congress organisers once again pursued the goal of primarily presenting the future in the lectures, which is why the focus was not on case reports or the presentation of individual studies, but rather on current development directions and visions.



Three thematic blocks captivated the auditorium:

Session 1: Bone and hard-tissue regeneration

When it comes to bone and implant issues, there is only one expert speaker, and it was he who took the microphone: Prof. Dr Dr Peer Kämmerer with his lecture "Bone lost—don't despair!". "I have a little coup de main planned for you," said Kämmerer, who dedicated the first part of his presentation to patient-specific factors that can reduce the success of oral implantation. In this regard, the use of antidepressants and proton inhibitors had proved to be detrimental to implant success.

The second part of his presentation addressed the options for augmentation. If all materials are available, simple defects can best be augmented using a membrane.

For more complicated dehiscence defects, the Mainz-based oral surgeon recommends the combination of autologous bone and bone substitute materials as well as the use of PRF (platelet-rich fibrin) and a membrane.

The lecture given by Prof. Dr Dr Daniel Rothamel, who investigated the question "Blocks, shells, granules: which makes sense for bone augmentation?" was an ideal addition to the first presentation on the second day of the congress. Implantology can be very simple, although it can also be complicated from time to time, said Rothamel in his opening remarks. In complex cases, the oral and maxillofacial surgeon recommends not only looking at the defect alone, but also at its surroundings: "Stability and rest" were defined by him as the most important prerequisites for the success of augmentation. Numerous excellently documented case studies underpinned Rothamel's explanations.

Afterwards, Dr Torsten Conrad presented the concept developed by Prof. Dr Dr Dr Shahram Ghanaati on blood concentrates as mediators for promoting wound healing in oral medicine and asked: "Which role does PRF play?". "We are actually talking about autologous platelet concentrates," said Conrad, which however differ in the number of leukocytes, the concentration of fibrin and in the centrifugation protocols. While initial experience was gained with PRP (platelet-rich plasma) and PRGF (plasma-rich in growth factor) concentrates, the breakthrough in dentistry came with the development of the PRF concentrate. This is characterised by its simple extraction and wide range of possible applications.

The final evolutionary step is the i-PRF, which is characterised by a liquid matrix. Reducing the centrifugal power increases the number of available cells that can have a biologising effect. The advantages of the procedure, which could also be referred to as "guided open wound healing", are the avoidance of covering small defects, the minimisation of the wound margins, the avoidance of periosteal incision and the protection of the mucogingival line.

The panel discussion with the speakers concluded a very interesting and insightful morning session.

Session 2: Prosthetic concepts between basic and high-end

The second session focused on the tension between "high-tech or rather simple" and included three presentations with very different approaches, which nevertheless complemented each other perfectly.

Dr Peter Gehrke made a plea for simple prosthetic restoration concepts and spoke about "Maximum safety with minimum effort: How much implant prosthetics is really necessary?". He made it clear: "Minimal effort does not automatically mean using old techniques—quite the opposite: the new digital options support us in our goal to a significant extent." The aim must be to establish simple standard concepts in terms of material, effort, and insertion techniques.

Dental technician Oliver Beckmann and dentist Stefan Friedrich showed a completely different perspective describing the "implant-prosthetic high-end" and talking about template-guided bone ridge reduction and simul-

taneous template-guided insertion of implants in the edentulous mandible. A beneficial lecture delivered by practitioners for practitioners: dental technicians and dentists demonstrated the high level of cooperation that is possible in the dental practice—even for highly complex applications.

The speaker duo has considerable experience in the fabrication and application of templates for bone ridge reduction and subsequent implant placement. The fundamental prerequisite is that both partners are thoroughly familiarised with the complex planning material and that there is close coordination before and during the application as well as a subsequent re-evaluation. "Communication is the key!" underlined dental technician Oliver Beckmann.

The prosthetics session concluded with a presentation by Dr Peter Randelzhofer, speaking about his expertise in immediate implant placement in the aesthetic zone. Very few speakers have gained as much experience in this demanding field as the Bavarian implantologist. Thus, Randelzhofer was able to open his almost infinite treasure chest of experience and present fascinating case studies. Even cases in which the initial conditions were far from ideal were solved by immediate implant placement. However, according to Randelzhofer, "the absolute consideration of biological concepts is essential, everything else leads to failure!"

Session 3: All about ceramic implants and toxicological aspects

The congress ended with one more true highlight: three renowned speakers highlighted the topic of ceramic implants and toxicology in all its aspects and demonstrated the extraordinary level of development that has now been achieved in this area.

Prof. Dr Dr Michael Gahlert is the author of numerous studies on ceramic implants. Dr Dr Stefan Röhling excerpted the most important findings from this broad knowledge and was able to provide lasting proof of the effectiveness of this category of materials. A recently published meta-analysis was also presented and explained by the renowned Munich implantologist: its results show that the bone and soft-tissue behaviour of ceramic implants is not only equal to that of titanium, but even superior in some points.

With his "Update soft tissue around implants", Dr Alexander Müller-Busch complemented Gahlert's presentation with further scientific facts and long-term experience. At the same time, he agreed with the previous speaker in his assessment that ceramic implants are on a par with titanium implants in terms of reliability and safety and that they also have considerable advantages in terms of peri-implant soft tissue.

Dr Elisabeth Jacobi-Gresser has been active in the field of immune-related research on implants for many years. The pathoimmunological effects of titanium and zirconium oxide implants were an important part of her fascinating presentation. It is thanks to Jacobi-Gresser's work that numerous scientific studies have shown that zirconium oxide implants are clearly superior to titanium implants in a certain number of cases.

The 52nd International Annual Congress of the DGZI—a brief conclusion

At this year's DGZI congress in Hamburg, participants were once again able to experience a unique and innovative training event. However, there was more: due to the different perspectives of science, practice, politics and industry, an exciting level of interaction was achieved.

The DGZI once again entered new territory with its attempt to explore the urgent matter of what implantology will look like in five or perhaps ten years' time and what the political and economic framework conditions will be like by then.

"Hamburg was a great venue for the DGZI, many thanks to the Hanseatic city," DGZI President Dr Georg Bach summed up.

DGZI

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ITI International Team for Implantology

All about the patient: The ITI World Symposium 2024

The ITI World Symposium is back and better than ever: more than 50 world renowned speakers will present at the world's largest scientific implant dentistry event in Singapore from 9–11 May 2024. Building on its previous highly successful online edition, the ITI World Symposium 2024 once again puts patients at the centre of the action. Over three days, the more than 4,000 participants will experience real patients and their stories on stage. The speakers will discuss various treatment options based on the latest scientific evidence. But it does not stop there: world class clinicians will provide commentary on exclusively recorded clinical procedures live on stage.
"With our unique, patient-centred programme structure, we aim to combine practical, clinical insights with the discussion of scientific findings," explains ITI President Charlotte Stilwell. "We ran a survey in our community last year to identify the topics of currently greatest relevance, and these form the core of our scientific programme: soft-tissue management, GBR/bone augmentation, immediate implants, peri-implantitis and the digital workflow." ITI members as well as early registrations will benefit from significant discounts.

ITI International Team for Implantology · worldsymposium.iti.org

German Association of Dental Implantology (DGZI)

Continuing education at its best: The 53rd International Annual Congress of DGZI

The 2023 annual congress of the German Association of Dental Implantology (DGZI) has barely taken place and the organisers are already working tirelessly on the 2024 event. The 53rd International Annual Congress of DGZI will take place on 8–9 November at the Hilton Hotel Düsseldorf. Participants will experience as always a congress that sets the course for the future, raises new questions and provides answers, and also shows new paths in the interaction between participants, speakers and the industry. This content-related approach will also be reflected in the congress programme and the innovative organisational concept.
Specifically, this means sharpening the profile of the congress as a joint event for practitioners, dental assistants, and dental technicians. The congress will offer strategy lectures, broadcasts of surgical tutorials and table clinics as well as high-quality scientific lectures, which will particularly take into account the information needs of implantologists in private practice. Table clinics and an exhibition concept, which is also an integral part of the programme, will play a more important role. Communication between all those involved in the congress will be a key factor on both days.
The aim of the congress is to offer first-class practical training at the highest level and to build a bridge between the latest scientific insights from the university sector to the demonstration of innovations and their implementation in daily practice. Renowned speakers will cover the entire spectrum of modern implantology in their lectures. Table clinics from manufacturers and suppliers of implants, membranes, and bone replacement materials, as well as a separate congress for the implantological team will complete the programme.
Enjoy two content-rich and instructive training days and enjoy the beautiful Rhineland city of Düsseldorf. Stay tuned for more details coming soon!

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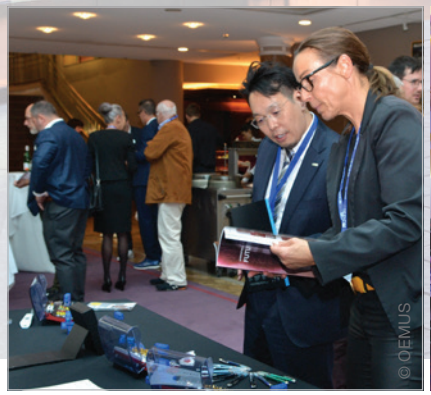
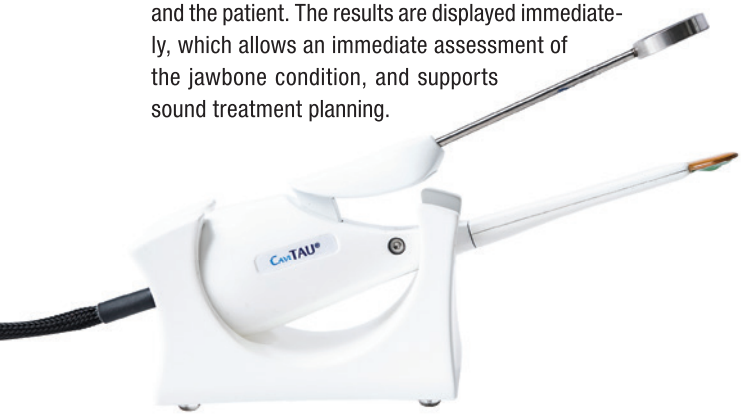
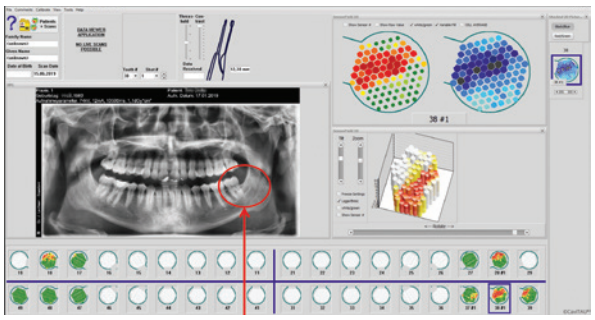


CaviTAU

The fourth dimension of dental implantology

CaviTAU—The groundbreaking invention for radiation-free, highly effective and safe measurement of jawbone density.
A new chapter in dental diagnostics has begun and its name is CaviTAU. This innovative jawbone density meter represents a breakthrough invention that takes jawbone density measurement to a new level. With CaviTAU, dentists can now measure jawbone density radiation-free, in a highly effective and safe way.
Imaging with a simple 2D X-ray is not thorough enough to diagnose harmful changes in the jawbone. Bone densitometry using DVT is also too inaccurate in the jaw region, as it cannot always accurately image Fatty Degenerative Osteonecroses.
With CaviTAU this problem is a thing of the past. The instrument uses state-of-the-art ultrasound technology that allows precise measurement of jawbone density without the need for radiation. This non-invasive method is not only safe for the patient, but also extremely effective and accurate.
Another advantage of CaviTAU is its efficiency. Measurements can be taken quickly and easily, which is beneficial for both the dentist and the patient. The results are displayed immediately, which allows an immediate assessment of the jawbone condition, and supports sound treatment planning.





The reliability of CaviTAU makes it a valuable tool in the dental office. The thorough measurements enable the dentist to make accurate diagnoses and create individualised treatment plans. This is especially crucial for implantation and other oral surgical procedures, as accurate knowledge of jawbone density is essential for the success of these procedures.
In addition to accuracy and safety, CaviTAU also has the advantage of patient convenience. The non-invasive and painless nature of ultrasound measurement ensures a comfortable patient experience. This is especially important in minimising patient anxiety and fear and increasing confidence in the treatment process.
CaviTAU undoubtedly has the potential to revolutionise dental diagnostics. Radiation-free, highly effective and safe measurement of jawbone density enables improved patient care and supports dentists in providing high-quality treatments.

Digital Dental & Healthcare Technology, Germany
www.cavitau.de

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19–20 January 2024
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www.efp.org

ITI World Symposium

9–11 May 2024
Singapore
worldsymposium.iti.org/

FDI World Dental Congress

12–15 September 2024
Istanbul, Turkey
www.fdiworlddental.org

National Osteology Symposium

26–28 September 2024
Paris, France
osteology.org

IAO-EAO-SIdP Joint Meeting

24–26 October 2024
Milan, Italy
congress.eao.org/milan/en/

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IMPLANTOLOGY

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