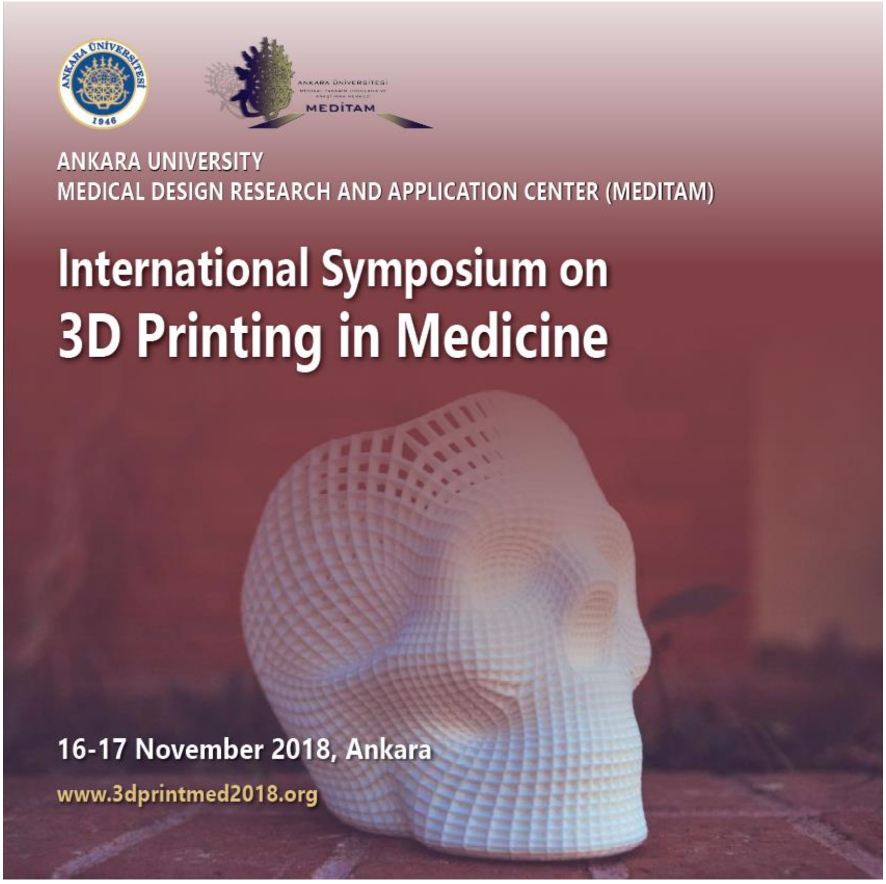
International Symposium on 3D Printing in Medicine

16-17 November 2018, Ankara, Turkey



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Welcome Address of the Symposium President

Dear Colleagues,

It is our great pleasure to invite you to participate in the International Symposium on 3D Printing in Medicine to be held during 16-17 November 2018 at Ankara University, Turkey. The meeting is organized by Ankara University Medical Design Research and Application Center, MEDITAM. The Symposium will bring together clinicians, researchers and industry to communicate, to exchange ideas and to discuss recent developments in the field of medical 3D printing.

Application of 3D printing technology in the medical field has created great impact on the therapy options enabling personalized treatment procedures and this impact is expected to grow exponentially over the future decades. 3D printing enables fabrication of customized medical implants and devices, surgical tools, medical training material and even human tissues and organs through bioprinting.

The Symposium will provide insights into these applications through lectures by world renowned Keynote and Invited speakers as well as hands-on sessions on 3D modeling and 3D printing.

The Symposium will be held at Ankara University School of Medicine, one of the most important medical centers in Turkey.

We hope to welcome you all to the International Symposium on 3D Printing in Medicine in Ankara, Turkey!

Sincerely,

Assoc. Prof. Dr. Pınar Yılgör Huri, PhD
On behalf of
Ankara University MEDITAM

International Symposium on 3D Printing in Medicine
16-17 November 2018, Ankara, Turkey

PROGRAM SCHEDULE

16 November 2018, Friday

08:00-09:00	Registration
09:00-09:30	Opening
Session-1	**Introduction to Basics and Applications of 3D Printing in Medicine** Chair: Prof. Dr. Feza Korkusuz
09:30-10:00	KEYNOTE TALK Prof. Dr. Alvaro Mata (Queen Mary University of London, UK) *From molecules to functional materials and devices for tissue engineering through supramolecular biofabrication*
10:00-10:30	KEYNOTE TALK Dr. Mostafa Ezeldeen (OMFS-IMPATH Research Group, KU Leuven, Belgium) *3D printing for tooth autotransplantation: outcomes, patterns of healing and lessons learned for bio-engineerd tooth transplantation*
10:30-10:50	Coffee Break
Session-2	**Orthopaedic Applications of Additive Manufacturing** TOAK Session Chair: Prof. Dr. Alpaslan Şenköylü
10:50-11:05	Prof. Dr. Feza Korkusuz (Hacettepe University) *Tissue engineering applications*
11:05-11:20	Industry Presentation Fausto Sbaiz (Lima Corporate Orthopaedic Medical Devices, Italy) *Custom-made orthopaedic implants*
11:20-11:35	Prof. Dr. Alpaslan Şenköylü (Gazi University) *Patient specific guides in spine surgery*
11:35-11:50	Asst. Prof. Dr. Can Gemalmaz (Acıbadem University) *Applications in arthroplasty*
11:50-12:05	Assoc. Prof. Dr. Kerim Sarıyılmaz (Acıbadem University) *Correction of extremity deformities with patient specific guides*
12:05-12:20	Assoc. Prof. Dr. Gazi Huri (Hacettepe University) *3D modeling and printing in orthopaedic surgery*
12:20-13:30	Lunch Break
Session-3	**3D Printing in Plastic and Reconstructive Surgery** Chair: Assoc. Prof. Dr. Burak Kaya
13:30-14:00	KEYNOTE TALK Prof. Dr. Jong-Woo Choi (University of Ulsan, South Korea) *Clinical applications of 3D computer simulation and 3D printing technology in craniofacial reconstructions*
14:00-14:20	Prof. Dr. İbrahim Vargel (Hacettepe University) *3D printed models for surgical planning and applications in craniofacial surgery*
14:20-14:40	Prof. Dr. Halil İbrahim Canter *3D implant design by virtual surgical planning and clinical applications in craniofacial surgery*
14:40-14:55	Assoc. Prof. Dr. Kemalettin Yıldız (Bezmialem Vakıf University) *Reconstruction of mandible using virtual surgical planning*
14:55-15:10	Dr. Şeyda Güray Evin (Selçuk University) *Preoperative 3D planning by means of mirror imaging in the unilateral zygomatic arch fracture*
15:10-15:25	Dr. Hasan Büyükdoğan (Ankara University) *An overview of 3D printing applications for plastic and reconstructive surgery*
15:25-15:45	Coffee Break
Session-4	**3D Reconstruction and Modelling for Surgical Anatomy** Chair: Prof. Dr. Ayhan Cömert
15:45-16:00	Prof. Dr. Figen Gövsa Gökmen (Ege University) *Surgical experience in anatomical reduction of ortopaedic surgery with 3D models*
15:55-16:05	Prof. Dr. Mehmet Asım Özer (Ege University) *Anatomical and functional outcome of surgical planning tool as actual size 3D models in calcaneal fractures*
16:05-16:15	Prof. Dr. Necdet Kocabıyık (University of Health Sciences) *3D medical printing with ABS plastic: METUM experience*
16:15-16:30	Prof. Dr. Erhan Kızıltan (Başkent University) *Rapid prototyping for patient specific vascular interventional training*
16:30-16:40	Prof. Dr. Tuncay Peker (Gazi University) *Creating new models in neuroanatomy training by using 3D printing*
16:40-16:50	Assoc. Prof. Dr. Banu Alıcıoğlu (Zonguldak Bülent Ecevit University) *3D imaging of a glomus caroticum tumor and obtaining of a 3D model*
16:50-17:00	Dr. İhsan Doğan (Ankara University) *Preoperative analysis of intracranial vascular malformations on 3D printed models*
17:00-17:10	Dr. Burak Bilecenoğlu (Ankara University) *3D teeth morphology using micro CT: Considerations for 3D printing*
17:10-17:20	Assoc. Prof. Dr. Kenan Köse (Ankara University) *Personalized Medicine: a machine learning approach to investigate possible network structure of lung cancer for targeting cancer specific pathways*

17 November 2018, Saturday

08:00-09:00	Registration
Session-5	**Biofabrication and Biomanufacturing** Chair: Assoc. Prof. Dr. Ayşe Karakeçili
09:00-09:30	KEYNOTE TALK Prof. Dr. Bahattin Koç (Sabancı University) *3D bioprinting with live cells for tissue/organ engineering*
09:30-10:00	KEYNOTE TALK Assist. Prof. Dr. Carlos D. Mota (Maastrich University, The Netherlands) *Development of alginate-based bioink for bioprinting tissue engineering applications*
10:00-10:20	Industry Presentation Dr. Carlos Carvalho (Envisiontech, Germany) *Thermoplastic materials in additive manufacturing assisted tissue engineering*
10:20-10:35	Industry Presentation Dr. Lim Jing (Osteopore International, Singapore) *Clinical applications of Osteopore regenerative technology*
10:35-11:00	Coffee Break
Session-6	**3D Printing in Tissue Engineering and Regenerative Medicine** Chair: Assoc. Prof. Dr. Pınar Yılgör Huri
11:00-11:15	Asst. Prof. Dr. Ali Akpek (Gebze Technical U.) *Microextrusion applied 3D biofabrication of endothelialized myocard tissue*
11:15-11:30	Asst. Prof. Dr. Mustafa Aslan (Karadeniz Tech. U.) *Manufacturing and pull-out testing of 3D printed human-like vertebra models*
11:30-11:40	Şeyda Gökyer (Ankara University) *3D printing of elastomeric biomaterials*
11:40-11:50	İbrahim H. Erbay (Izmir Biomedicine and Genome C.) *Developing 3D printed scaffold masters for microfluidic bioreactors*
11:50-12:00	Seren Keçili (Izmir Institute of Technology) *3D printing strategy to fabricate microfluidic devices with enhanced optical transparency*
12:00-12:10	Sefa Aydın (Bursa Technical University) *Developing an artificial human auricle fabricated in polyurethane by an FDM 3D printer*
12:10-12:20	Bora Tüleylioğlu (Başkent University) *Placental membrane mesenchymal stem cell culture in 3D printed scaffold: preliminary results*
12:20-13:30	Lunch Break
Session-7	**Clinical Applications of 3D Printing** Chair: Asoc. Prof. Dr. İlkan Tatar
13:30-13:45	Prof. Dr. Kürşat Gökcan (Ankara University) *3D modelling and computational fluid dynamics experiments on upper airway obstruction surgeries*
13:45-14:00	Prof. Dr. Banu Karayazgan (Okan University) *The Role of Computer Aided Modeling and Manufacturing in Maxillofacial Prosthetics*
14:00-14:15	Asst. Prof. Dr. Öznur Özalp (Akdeniz University) *The role of 3D printing technology in contemporary oral and maxillofacial surgery*
14:15-14:25	Dr. Hasan Büyükdoğan (Ankara University) *Comparison of pre-operative surgical planning softwares for mandible reconstruction*
14:25-14:40	Asst. Prof. Dr. Murat Köken (Ufuk University) *Use of 3D printing in ortopaedic surgery: an analysis of the literature for the last 3 years*
14:40-14:50	Dr. Murat Gülçek (Ankara Numune Training and Research Hospital) *3D printed hip joint model in presurgical planning for a patient with congenital hip dislocation: a pilot study*
14:50-15:00	Dr. İhsan Doğan (Ankara University) *Augmented reality assisted cerebrovascular microsurgery using hand-held computer devices*
15:00-15:30	Coffee Break
Session-8	**3D Printing in Anatomy Education** Chair: Prof. Dr. Çağdaş Oto, Prof. Dr. Oktay Algın
15:30-15:45	Assoc. Prof. Dr. İlkan Tatar (Hacettepe University) *3D modelling, its related technological modalities and 3D printing in anatomy curriculum*
15:45-16:00	Asst. Prof. Dr. Hale Öktem (Başkent University) *Use of 3D modeling and manifacturing in anatomy education*
16:00-16:15	Dr. Mehmet Ali Güner (Ankara University) *Investigation of variations of renal vessels with 3D modeling*
16:15-16:30	Assoc. Prof. Dr. Okan Ekim (Ankara University) *Real vs. artificial: Use of 3D printed materials instead of plastinated specimens in veterinary education*
16:30-16:45	Dr. Remzi Orkun Akgün (Ankara University) *3D printed skull models for comparative veterinary anatomy*
16:45-17:00	Dr. Caner Bakıcı (Ankara University) *The efficiency of 3D printed models of hyoid bone for better education in comparative anatomy*
17:00-17:15	Dr. Duygu Aslan (Eskişehir Osmangazi University) *Expectations of medical faculty students related to the use of 3D printing in anatomy education*

Abstracts of the International Symposium on 3D Printing in Medicine

16-17 November 2018, Ankara, Turkey

INVITED LECTURES AND ORAL PRESENTATIONS

OP-1. FROM MOLECULES TO FUNCTIONAL MATERIALS AND DEVICES FOR TISSUE ENGINEERING THROUGH SUPRAMOLECULAR BIOFABRICATION

Alvaro Mata

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Introduction
There is great interest to develop new materials with advanced properties that resemble those of biological systems such as hierarchical organization and the capacity to grow or self-heal. To this end, supramolecular chemistry offers an exciting opportunity to grow materials with nanoscale precision. However, the ability to transform molecular design into functional devices with utility at the macroscale remains a challenge.

Results and Discussion
The talk will describe new strategies that integrate supramolecular chemistry with engineering principles to develop practical materials with tuneable and advanced properties such as hierarchical organization[1,2], the capacity to grow[2,3], tuneable mechanical properties[2], and specific bioactivity[4]. These materials are being used to develop new regenerative therapies of tissues such as enamel, bone, and blood vessels as well as more biologically relevant *in vitro* models for applications in cancer and neurological disorders.

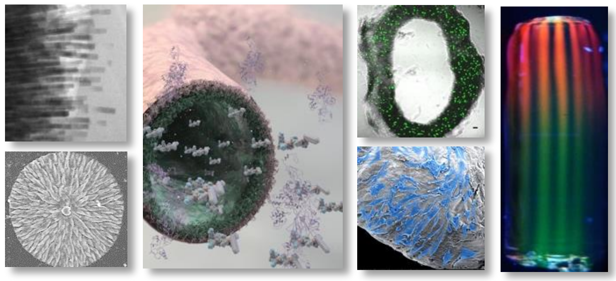

Figure. Sample images of functional materials and devices made by supramolecular biofabrication.

References
1. Hedegaard et al, (2018). *Advanced Functional Materials* 10.1002/adfm.201703716.
2. Elsharkawy et al, (2018). *Nature Communications* 10.1038/s41467-018-04319-0.
3. Inostroza-Brito et al, (2015). *Nature Chemistry* 7(11), 897-904. 10.1038/nchem.2349.
4. Aguilar et al, (2017). *Advanced Functional Materials* 10.1002/adfm.201703014.

OP-2. 3D PRINTING FOR TOOTH AUTOTRANSPLANTATION: OUTCOMES, PATTERNS OF HEALING AND LESSONS LEARNED FOR BIO-ENGINEERD TOOTH TRANSPLANTATION

Mostafa Ezeldeen

OMFS-IMPATH Research Group, KU Leuven, Belgium

Tooth autotransplantation (TAT) offers a viable biological approach to tooth replacement in children and adolescents after traumatic dental injuries (TDIs), agenesis, developmental anomalies or specific orthodontic problems. The treatment options available, for example implant placement, are limited by the ongoing dentoalveolar development, while, orthodontic tooth alignment may frequently result in suboptimal esthetic results. TAT allows for periodontal healing and enables preservation of the alveolar ridge maintaining the possibility of function and growth. To enhance outcome predictability of the TAT procedure, a low-dose cone-beam computed tomographic (CBCT)-guided surgical planning and transfer technique has been developed, involving donor tooth selection and tooth replica fabrication. This lecture will cover the outcomes and the patterns of healing of CBCT-guided TAT compared the conventional approach. Further, lessons that can applied for bio-engineerd tooth transplantation will be discussed in addition to initial results.

OP-3. 3D BIOPRINTING WITH LIVE CELLS FOR TISSUE/ORGAN ENGINEERING

Bahattin Koç

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Bioprinting is a relatively new tissue/organ engineering method where living cells with or without biomaterials are printed layer-by-layer in order to create three-dimensional living structures. In comparison to scaffold-based tissue engineering approaches, this method fabricates complex living and non-living biological structures from live cells alone or with biomolecules and biomaterials. This presentation will discuss about direct 3D bioprinting of cell aggregates and also cell-laden hydrogels for tissues/organ engineering. Bioprinting process such as how to digitally copy and design tissue/organs, how to prepare bio-inks, bio-printing instructions and how to print live cells will be explained. The presentation will also discuss the several applications and also the challenges in organ printing.

OP-4. DEVELOPMENT OF ALGINATE-BASED BIOINK FOR BIOPRINTING TISSUE ENGINEERING APPLICATIONS.

Carlos Mota[1], Huey Wen Ooi[1], Johanna Bolander[2], Frank Luyten [2], Matthew Baker[1], Lorenzo Moroni[1]

[1] MERLN Institute for Technology-Inspired Regenerative Medicine, Maastricht University, Maastricht, the Netherlands.
[2] Skeletal Biology and Engineering Research Center, Katholieke Universiteit Leuven, Belgium.
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Introduction
Bioprinting are a group of powerful additive manufacturing techniques that allows precise and controlled 3D deposition of biomaterials in a predesigned, customizable, and reproducible manner.[1] Cell-laden hydrogel ("bioink") bioprinting where multiple cells and biomaterial compositions can be selectively dispensed are an advantageous approach to develop tissue and organs exploring tissue engineering approaches. Only a few hydrogel systems are easily available and suitable as bioinks and little amount of these systems allow molecular design of mechanical and biological properties. In this study, we report the development of a norbornene functionalized alginate system as a cell-laden bioink for extrusion-based bioprinting.[2]

Methods
Alginate (FMC) was purified and the M/G block were quantified with NMR. The alginate was functionalized with norbornene methylamine (Alg-nor) and conjugated with RGD (Alg-nor-RGD) (Figure 1). Thiol-Ene

reaction were performed with UV crosslinking of the hydrogels with optimized lithium phenyl (2,4,6-trimethylbenzoyl)phosphinate and with different polyethylene glycol (PEG) linkers (PEG dithiol 1500, PEG dithiol 5000, and 4-arm PEG 5000). Swelling and water uptake was evaluated for the different hydrogels prepared. Biocompatibility and cell viability was evaluated with fibroblast and chondrocyte cell lines before and after bioprinting. The developed hydrogel formulations were used for the manufacturing of triple layer constructs to mimic callous formation for the treatment of large bone defects. These tissue-engineered implants were bioprinted by combining alginate-based hydrogels with human periosteum-derived cells. Subcutaneously implantation was performed on mice for 4 weeks.

Results and Discussion

Tuning the alginate concentration, length, and structure of dithiol PEG crosslinkers allowed a wide range of mechanical and swelling properties of the hydrogels. Secondary crosslinking post-printing with divalent ions such as calcium allowed improved mechanical properties. Bioinks were prepared with concentrations below 2 wt % and these showed a fast *in situ* gelation allowing high cell viability. Different bioinks were used to fabricate large multilayer or multi-bioink constructs with identical bioprinting conditions. Human periosteum-derived cells bioprinted in single cell or in aggregates in combination with the different hydrogels showed a high cell viability.

Conclusion

The modularity of this bioink platform enables a rational design of materials properties but also the gel’s biofunctionality such as by the addition of RGD. This flexibility allows the application of this materials for diverse tissue-engineering application. This modularity enables the creation of multizonal and multicellular constructs utilizing a chemically similar bioink platform. Such tailorable bioink platforms will enable increased complexity in 3D bioprinted tissue constructs.

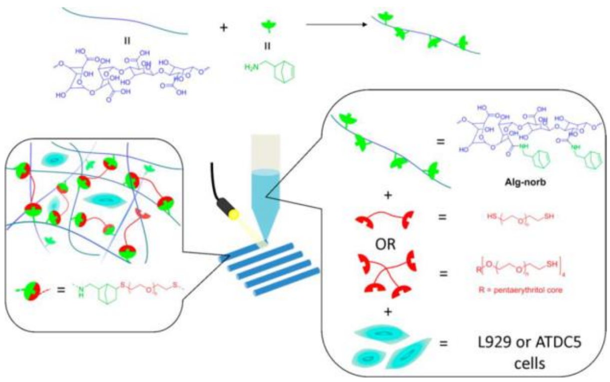

Figure 1. Strategy employed to develop photoactive alginate bioink (Alg-norb) for bioprinting of hydrogels[2].

References

1. Mota, C.; Puppi, D.; Chiellini, F.; Chiellini, E., Additive manufacturing techniques for the production of tissue engineering constructs. J Tissue Eng Regen Med 2015, 9 (3), 174-90.
2. Ooi, H. W.; Mota, C.; Ten Cate, A. T.; Calore, A.; Moroni, L.; Baker, M. B., Thiol-Ene Alginate Hydrogels as Versatile Bioinks for Bioprinting. *Biomacromolecules* **2018,** *19* (8), 3390-3400.

Acknowledgements

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OP-5. TISSUE ENGINEERING APPLICATIONS

Feza Korkusuz

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High-energy trauma after road traffic accidents, fall from height or gunshot wounds causes major musculoskeletal tissue loss that needs to be replaced by engineering. Three-dimensional (3D) printers are recently preferred to construct the extracellular matrix with cells to reconstruct bone, skeletal muscle, joint cartilage, ligaments and tendons. The technology has evolved from rapid prototyping to Selective Laser Sintering (SLS), Fused Deposition Modeling and Laminated Object Manufacturing. 3D printing is mainly used for surgery planning of complex anatomical structures such as the hip joint, personalized implant and prosthesis production. The technology is mostly used in maxillofacial reconstruction and knee prosthesis development. Advantages of 3D tissue printing are pre surgery planning, accuracy of implantation, decrease of surgery time, cost and complications, training and ease of revision. A challenge is the development of a nozzle that can print the inorganic matrix of bone with cells and extracellular matrix. Novel research on such studies including electrospinning will be discussed.

OP-6. PATIENT SPECIFIC GUIDES IN SPINE SURGERY

Alpaslan Şenköylü

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Introduction

Additive manufacturing, so called three-dimensional printing (3DP) allows for the rapid conversion of anatomic images into physical components by the use of special printer. This technology allows for a more personalized approach towards spine surgery. In the setting of spinal deformity, it provides cheap and fast template production to facilitate pedicle screw insertion in spinal deformity patients. Currently, 3D printing has been used to address several spinal disorders and/or conditions, such as the development of an intervertebral disc and vertebral bodies.

Methods

Eleven (9 females, 2 males; mean age: 15 years old) AIS patients were included in this study from a single institution. After selecting fusion levels and fixation points, 3D guides were produced for all individual levels. Preoperatively, 0.63 mm thickness sliced CT scan images were transferred to a materialize interactive medical image control system and 3D bone models of each vertebra were created. Safe pedicle trajectories were determined in all three planes on these models. 3D guides were modelled according to these trajectories and manufactured with a 3D printer from a biocompatible material 3DP guides were used during surgeries of AIS patients. Postoperatively, all screws were evaluated and scored with CT images.

Results and Discussion

There were 134 screws (67 convex and 67 concave) inserted in total. The cost of a 3DRP guide per level was €2. On the concave and convex sides, the mean medial malposition was 0.5±0.78-0.4±0.62, the mean lateral malposition was 1.43±2.33-0.83±1.27, ASIT was 4.18±4.63 and 4.28±5.99, and DBSP was 1.45±2.11 and 0.93±1.24, respectively. One-hundred and seventeen Class-1, 14 Class-2, and 3 Class-3 penetration. There was a 92.5% positional accuracy of the screws (n=134 inserted screws). There was no screw-related complications.

Conclusion

This is the first study to report the implementation of 3DRP guides for the application of pedicle screws in AIS. Our study showed that the use of these low-cost guides is safe, can be applied in rotated pedicles.

References

1. Malik HH, Darwood AR, Shaunak S, et al. Three-dimensional printing in surgery: a review of current surgical applications. *J Surg Res.* 2015;199:512-522.
2. Bowles RD, Gebhard HH, Hartl R, Bonassar LJ. Tissue-engineered intervertebral discs produce new matrix, maintain disc height, and restore biomechanical function to the rodent spine. *Proc Natl Acad Sci U S A.* 2011;108:13106-13111.

3. Kaneyama S, Sugawara T, Sumi M, Higashiyama N, Takabatake M, Mizoi K. A novel screw guiding method with a screw guide template system for posterior C-2 fixation: clinical article. *J Neurosurg Spine.* 2014;21:231-238.
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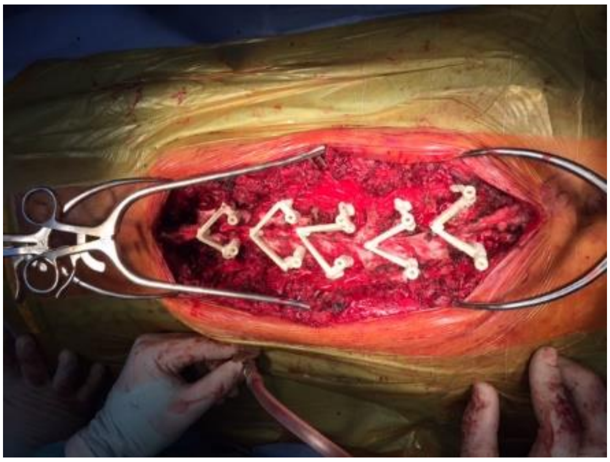


OP-7. POSTOPERATIVE MECHANICAL ALLIGNMENT ANALYSIS OF TOTAL KNEE REPLACEMENT PATIENTS OPERATED WITH 3D PRINTED PATIENT SPECIFIC INSTRUMENTS

Halil Can Gemalmaz[1], Kerim Sarıyılmaz[2], Okan Ozkunt[3], Mustafa Sungur[2], Ibrahim Kaya[2], Tunca Cingoz[1], Fatih Dikici[1], cgemalmaz@gmail.com

1 Acıbadem Mehmet Ali Aydınlar University, School of Medicine, Department of Orthopaedics and Traumatology
2 Acıbadem Mehmet Ali Aydınlar University, Faculty of Health Sciences
3 Medipol University, Sefakoy Hospital

Introduction
To compare the mechanical alignment results of patients operated with computerized tomography (CT) based local production patient specific instruments (PSI) and conventional instruments.

Methods
34 patients whom had total nnee replacement (TKR) surgeries had been included in the research. There are 17 patients each in patient specific instruments (PSI) and conventional instruments (CI) groups. All operations had been performed by the same two surgeons with cruciate retaining incision guides are designed by “Metaklinik” with consultations from the physicians and produced from polyamide material via 3D printing. PSI guides are used for tibial and distal femoral incisions after routine sterilization processes. Mechanical FemoroTibial Angle (mFTA), Femoral Coronal Angle (FCA) and Tibial Coronal Angle (TCA) via Weight Bearing Orthoroentgenograms are used for assessing postoperative mechanical alignment. Differences between the groups were evaluated statistically via Mann-Whitney U test. Additionally, results with ±3° deviation are evaluated statistically via Chi-Square test.

Results and Discussion
PSI group (1) had 12 female and 5 male (2 are bilateral) patients and CI group (2) had 16 female and 1 male patient (2 are bilateral). Mean ages were 68.58 and 72.17 for each group respectively.
Pre-operational mFTA were 168.35 and 168.76, Post-operational mFTA were 177,84 and 176.02 again respectively for each group. Mean FCA values were 89.92 for group 1 and 87.76 for group 2. Mean TCA were 89.88 for group 1 and 89.24 for group 2. Group 1 had 1 (5.9%) patient and group 2 had 7 (41.2%) patients that had a ±3° deviation from the optimal mechanical axis in postoperative mFTA values. Without regard to the mechanical axis 2 incisions (5.9%) and 12 incisions (35.3%) in groups 1 and 2 respectively had a ±3° deviation in FCA and TCA measurements.
The statistical analysis (FKA (p=0.032)) benefits PSI group in regard to the findings,

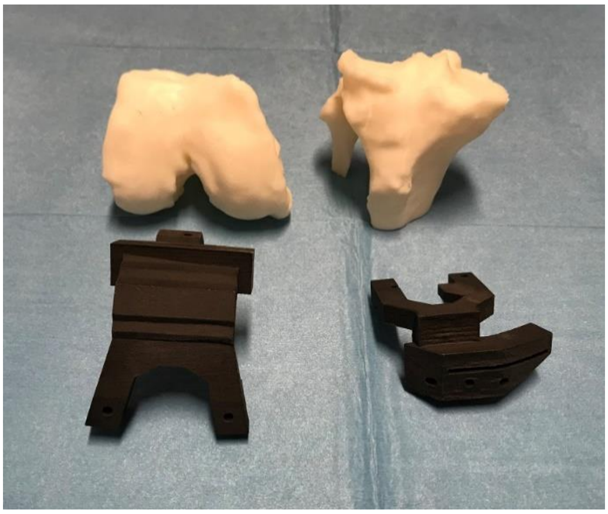
- Number of extreme values that causes ±3° deviation in mechanical axis [X^2 1, N=34)=5.88, p=0.01]
- Number of extreme values that causes ±3° deviation in FCA and TCA

without regard to mechanical axis [X^2 1, N=34)=8.99, p=0.00]

Additionally, analysis of TCA, pre-operative and post-operative mFTA results showed no statistically significant differences between the two groups.

Conclusion

It is known that total knee arthroplasties increase the risk of early failure of 3 degree extreme values seen on mechanical axis. In our study, significantly lower extreme values were found in the group used PSI. In our series of limited number of patients, associated with differences in mechanical alignment value weren't statistically significant, significantly fewer extreme values in PSI may contribute positively to the survival of knee arthroplasties. Because different terminology is used to express the same angular data, the data set was made uniform using the terminology outlined by MacDessi et al. The number of outliers (cases without alignment within ±3°) was determined for each group, each study, and each endpoint by comparing the percentage of procedures with a neutral alignment (i.e. within 3°). The risk of early failure is reduces and survival increases when implants are placed within ±3° of the mechanical axis.



OP-8. RECONSTRUCTION OF MANDIBLE USING VIRTUAL SURGICAL PLANNING

Kemalettin Yıldız

Bezmialem Vakif University, Dept. of Plastic Reconstructive & Aesthetic Surgery, Istanbul, Turkey, yildizkemalettin@gmail.com

Introduction

Evolution in reconstructive microsurgery depends on the increase in demands, advances in surgery and technology. We present mandible reconstruction using virtual surgical planning and cutting-guides manufactured by 3D printers.

Methods

Traumatic or oncologic defects of mandible were reconstructed with free vascularized fibula flaps using virtual surgical planning and cutting-guides. The maxillofacial 3D computerized tomography scans of patients were taken. DICOM data were transformed to STL format. Segmentation and virtual surgical planning were performed with software. The cutting guides for osteotimies, occlusal splint model, craniomaxillofacial model of patients designed virtually and manufactured in 3D printers.

Results and Discussion

We presented the application of virtual surgical planning and custom made implants such as cutting guides, models, plates. Implants were sterilized and used in vitro and intraoperatively. Precise and delicate osteotomies have been performed. Also full bony contact in osteotomy sites has been achieved. However, this technique needs a learning curve and the cost is the main limitation of its use[1].

Conclusion

Superior aesthetic and functional results can be achieved with the use of this technique and implants.

References

1. Largo RD, Garvey PB. Updates in head and neck reconstruction. Plast Reconstr Surg 2018; 141(2):271e-285e.

OP-9. PREOPERATIVE 3D PLANNING BY MEANS OF MIRROR IMAGING IN THE UNILATERAL ZYGOMATIC ARCH FRACTURE

Seyda Guray Evin, Cemil Isık, Osman Akdag, Zekeriya Tosun

[1] Selcuk University, Department of Plastic Surgery,Turkey

Introduction

Isolated zygomatic arch fractures make up 5-10% of complex zygomaticomaxillary injuries.[1] Restricted mouth opening sometimes can be seen but facial collapse as another symptom can be concealed by tissue edema in early period. Due to this fact, it may be difficult to show that the facial form is restored properly after zygomatic arch fracture surgery. Preoperative 3D planning is gaining importance as a facilitating factor in zygomatic arch fracture surgeries also. The aim of this study is to describe preoperative 3d planning in the unilateral zygomatic arch fracture with help of mirror imaging.

Methods

Between April 2013 and January 2016, 8 patients who applied to our clinic with zygomatic arch fractures were operated with preauricular endoscopic approach (Table1) Indications of surgery were there was isolated and comminuted zygomatic arch fracture needed to be rigit fixation. Preoperatively, shape and component of the fracture were determined with 3D computerized tomography. A possible facial asymmetry was ruled out by evaluating of old photos of the patients. Dicom data from 3D tomography were transferred to the simplant software (Materialize Dental, Leuven, Belgium). Preoperative plate preparation was done in 2 methods. In the first method, a mirror image of isolated part of the unfractured zygomaticomalar region was obtained and printed. This was used as a guide in bending the plate. In the second method, mirror image of unfractured zygoma was obtained in simplant software. As a differences from the first method, shaping of the plate was done in software without 3D printing. Afterward already shaped plate was printed and used as a guide in bending titanium plate. Shaped titanium plates were sterilized for using in operation.

Results and Discussion

Seven male and 1 female patient were operated on with the preauricular endoscopic approach. The average age of the patients was 33.6 (range, 16-64) years. The etiologic agent in 3 patients was a traffic accident, in 3 physical assault, and in 2 a fall. In all patients, a localized depression was present in the trauma area. The average hospital length of stay for all patients was 1.6 days. The average operative time was 3 hours. In the intraoperative period, none of the patients had a major complication. Postoperative 3D tomography showed that both zygomatic arches were symmetrical in all cases. Temporal branch injury occurred after surgery in 1 patient. This injury was improved at 1-year follow-up. No temporal hollowing was seen in any patient. All patients were followed up for 12 months. The facial contour was symmetrical in all patients at 1 year postoperatively, and the scar in front of the ear was inconspicuous. The plate was palpable on the zygomatic arch only in 1 patient. No surgical procedure was performed.

Conclusion

Zygomatic arch is the most important part of zygoma contributing to facial projection. However, unlike maxilla or mandible, there is no factor which shows effective repair of zygomatic arch fractures during operation. The most important indicator of effective repair is the symmetrical reconstruction of the facial projection. In this study, we performed mirror imaging in various anatomical regions where included the zygomatic arch in order to increase the accuracy of surgical procedure and restore facial projection most symmetrical in repairing zygomatic arch fractures. We think that mirror imaging and preoperative plate shaping is the most current treatment option considering low cost, low operation time, good operation result.

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OP-10. 3D PRINTING IN PLASTIC AND RECONSTRUCTIVE SURGERY

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Introduction
Since the emergence of three-dimensional printing in the 1980’s, it has become possible to produce physical objects from digital files and follow a predetermined pattern to add one layer at a time and create three-dimensional objects. As a result of the development of cheap and easy-to-use three-dimensional printers, and particularly bioprinting technology, the use of this rapid prototyping technique has gained momentum in the last 10 years in medicine. The aim of this study is to review the utilization of 3D printing technology in the field of plastic surgery.

Methods
We have reviewed the English literature for active and possible utilization areas of 3D printing in plastic and reconstructive surgery and documented them accordingly.

Results and Discussion
The combination of computer-aided design and 3D printing techniques enable pre-op virtual surgical planning, customized surgical plate and screw design and patient-specific implants. Biomimetic hand, finger and arm prostheses with tactile and thermal stimulation are developed specifically for each patient's anatomy to eliminate the loss of form and function due to trauma or congenital conditions. To prevent excessive scarring especially in the face area, printing a patient-specific face mask and starting the compression treatment early is a feasible method after burn injury. In the reconstruction of tissue losses due to trauma, oncological surgery or congenital conditions, tissue compatible biomaterials can be produced with 3D technologies with high success rates. 3D printing is utilized as an alternative to cadaver dissection in surgical training. With this method, it may decrease the morbidity rates of surgical assistants to increase their orientation of the surgical field and hand skills before surgery. In order to explain the anatomically complex cases to the patients and to give them more detailed information about their situations, 3D printed models can be used, and this may increase the patients’ compliance to the treatment.

Conclusion
3D printing has a wide range of possible utilization areas in the scope of plastic and reconstructive surgery and as the printing technology develops, we will be witnessing more ground-breaking advances in this field.

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OP-11. SURGICAL EXPERIENCE IN ANATOMICAL REDUCTION OF ORTOPAEDIC SURGERY WITH 3D MODELS

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Introduction
Orthopedic surgery involves some important and specific problems, including the choice of correct operative approach, reduction of bone fragments, and determination of fixation patterns. Hence, recognition and comprehension of the fracture features will help orthopedic surgeons understand the injury mechanism better and manage these fractures by planning optimal surgical procedures. In this study, we investigated the surgical experience of the use of digitally designed 3D life-size fracture models for guiding template to place plates and screws for surgical treatment of fractures and anatomic reduction of joint.

Methods
A total of 20 patients with fractures were reviewed using their CT scans. For each patient, 3D fracture models were created. The detailed information of fracture models were used as a preoperative reference of anatomical reduction.

Results
3D models assisted in determining the fracture locations, depression depth, their types and the depression zones. Different type fracture, fracture depression, depression depth occurred at different locations of the fractures. Personalized models made possible to treat classified fractures as well as the unclassified, incompatible types and complicated cases. The location of the fracture, the relation with the fracture lines and the need for the graft were also determined. In this way, 3D printing technique showed to be an effective and reliable method for creating treatment algorithms in reducing operation, fluoroscopy time, less blood loss and resulting in a successful intervention.

Conclusions
The individualized 3D printing screw insertion template was user-friendly, and it enabled a radiation-free screw insertion. 3D models were used in surgical planning maximizing the possibility of ideal anatomical reduction as well as providing individualized information concerning fractures. As they provide successful intervention without complications and reduce both the operation and the fluoroscopy time with less blood loss, they should be preferred.

OP-12. ANATOMICAL AND FUNCTIONAL OUTCOME OF SURGICAL PLANNING TOOL AS ACTUAL SIZE 3D MODELS IN CALCANEAL FRACTURES

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Introduction
This study was aimed to compare conventional surgery and surgery assisted by 3D printing technology in the treatment of calcaneal fractures.

Methods
A total of 20 patients with calcaneal fractures were reviewed using their CT scans. They were divided randomly into two groups: 10 cases of 3D printing group, 10 cases of

conventional group. The individual models were used to simulate the surgical procedures and carry out the surgery according to plan in 3D printing group. Operation duration, blood loss volume during the surgery, number of intraoperative fluoroscopy and fracture union time were recorded. The radiographic outcomes Böhler angle, Gissane angle, calcaneal width and calcaneal height and final functional outcomes as complications were also evaluated.

Results

In this way, 3D printing technique showed to be an effective and reliable method for creating treatment algorithms in reducing operation, fluoroscopy time, less blood loss and resulting in a successful intervention. There was statistically significant difference between the conventional group and 3D printing group ($p < 0.05$). Additionally, 3D printing group achieved significantly better radiographic results than conventional group both postoperatively and at the final follow-up ($p < 0.05$).

Conclusion

The individualized 3D printing screw insertion template was user-friendly, and it enabled a radiation-free calcaneal screw insertion. 3D models were used in surgical planning maximizing the possibility of ideal anatomical reduction as well as providing individualized information concerning calcaneal fractures.

OP-13. RAPID PROTOTYPING FOR PATIENT SPECIFIC VASCULAR INTERVENTIONAL TRAINING

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Recent advances in patient specific three-dimensional (3D) modeling serve as the initial platform for developing educational materials, computational simulators and tools for prognostic foresight. It is apparent that any activity related with 3D modeling has a positive impact on mental imagery of students in all levels of education. Three-dimensional models also provide a base for 3D computations of physiological parameters. Therefore, 3D modeling applications are accepted as valuable tools for physician in choosing treatment modalities, as well. In this presentation I will introduce an application that we developed using our own software TT3D-BBP. The application provides a work station for manufacturing patient specific vascular models. This in turn provides effective desktop training platform for vascular interventions.

The application uses tomographic patient dataset. Interested vascular structure on two-dimensional image is segmented by an automatic feature extraction algorithm with the option of manual correction. When segmentations are completed in all selected slices the surface mesh model is created in a universal file format. Segmented geometry (virtual model) is 3D-printed with transparent polylactic acid filament and then fixed on a plate for vascular access training.

Since catheter-based interventions are becoming almost the first choice in vascular anomalies and every case has variations specific to the patient it is important to have better training and orientation to the vascular geometry before the intervention. The 3D-printed models are usually a close representation of the patient's anatomy therefore such applications will be an effective platform in building confidence in interventional radiologist/cardiologist.

OP-14. CREATING NEW MODELS IN NEUROANATOMY TRAINING BY USING 3D PRINTER

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Introduction

Anatomy is one of the most important lessons of medical education. A person who does not know good anatomy can not be a good physician and a talented surgeon. Medical students have difficulty in understanding the internal structures of some organs. Anatomical models are also inadequate in teaching of the complex anatomical structures. Accordingly, the student memorizes the topic without understands. The memorized topic is forgotten in upper classes.

Methods

In this study, mesencephalon was selected as an example in relation to the Neuroanatomy that the student was most difficult to understand. Cinema 4D program was used to modelling the internal structure of the mesencephalon. Internal structure of mesencephalon model was obtained from 3D printer as STL format. Each anatomical structure in the print-out was painted in different colors with acrylic model colors and then the internal structure was embedded in transparent polyester resin. After the polyester resin had hardened, the final version of the pattern was removed from the silicone mold.

Results

Models and educational tools that can show the brain stem nuclei and their internal anatomic structures are insufficient in the world[5]. This study is unique in the world with regard of this feature. When the model is keep in the hand, all internal structures, locations and neighborhoods in the space are visible clearly.

Conclusion

We started from mesencephalon to model the internal structures of the organs that make up the brain stem. Then the model of bulbus and pons will be created. These models are the first brainstorming works produced in the world using the latest technology. We think that medical students will learn much better with this model. We are also thinking about supporting the interior with electronic applications such as RGB LEDs and new interactive applications such as Augmented Reality.

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OP-15. 3D IMAGING OF A GLOMUS CAROTICUM TUMOR AND OBTAINING OF A 3D MODEL

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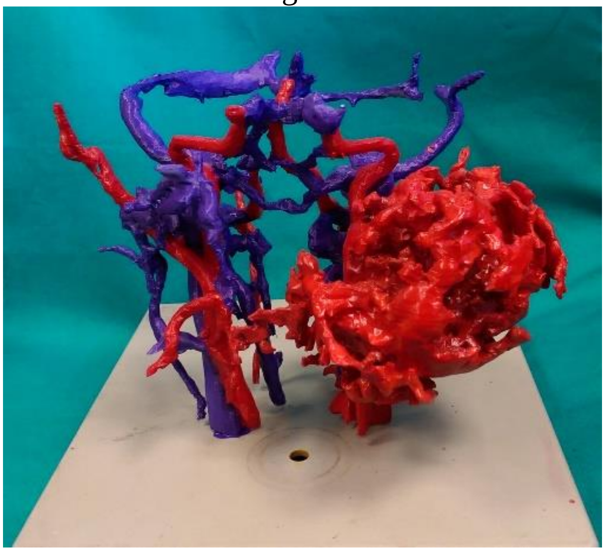
Introduction
Glomus tumor is usually a benign tumor that grows slowly but contains many blood vessels. It can occur in fingers, ear, neck, vagus nerve, skull and temporal bone, jugular vein, orbita, chest or abdomen.

Methods
In this study, a carotid body tumor in the neck of a 52 year old female patient was examined. The patient's MR Angiography images were taken as DICOM files and reconstructed with the Mimics software[9]. The resulting 3D model was saved to computer STL format. Then 3D print-out was obtained by using 3D printer. The 3D print-out was cleaned from the surrounding supports and artifacts. Since the arteries and veins were not distinguishable, the model was painted with red and blue model colors respectively.

Results
The obtained 3D model is very useful in diagnosis of the radiologist and the surgeon because the tumor model is the exact match of the real tumor of the same size. Surgical approach in small and complex areas such as head and neck is very important for the surgeon. Neighboring arteries and veins as well as the feeding and the draining veins of the tumor may alter incision and dissection. Planning before surgery, who takes the obtained model, will facilitate orientation of the surgeon and increase the success of the operation.

Conclusion
In the coming years, we think that this method will be routine for surgeons.



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OP-16. PREOPERATIVE ANALYSIS OF INTRACRANIAL VASCULAR MALFORMATIONS PURSUANT TO MICRONEUROSURGICAL TREATMENT ON LIFE-LIKE 3-DIMENSIONAL PRINTED MODELS

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Introduction

Medicine is an important branch of science that can certainly benefit from 3D-printing technologies. The designation, fabrication, and adaptation of feasible products made this growing technology more popular.[1,2]

Here, we aim to adapt these 3D-printing models to neurosurgery for better understanding the complex intracranial pathologies and produce patient-based individual neurosurgical treatment strategies.

Methods

The thin slices of MRI and CT angiography images of 23 patients were included in our study. These images were processed using Osirix software. STL files of these reformatted images were created and printed three-dimensionally with the skull.

Results and Discussion

The life-like 3D models of intracranial vascular structures were processed and created without any problem. The vessels with thickness smaller than 1mm could not be printed. Craniotomy/craniectomy procedures were easily performed and surgical angle of view was caught on every specimen.

Conclusion

Three-dimensional printed models of intracranial vascular pathologies allow neurosurgeons to understand the complex anatomy and relationship of these lesions with other neural, vascular and bony structures. Using life-size models, it is possible to test and simulate the surgery. These models are the best tools for practicing surgical steps.

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Figure. Printed models of intracranial arterial pathologies

OP-17. 3D TEETH MORPHOLOGY USING MICRO CT: CONSIDERATION FOR 3D PRINTING

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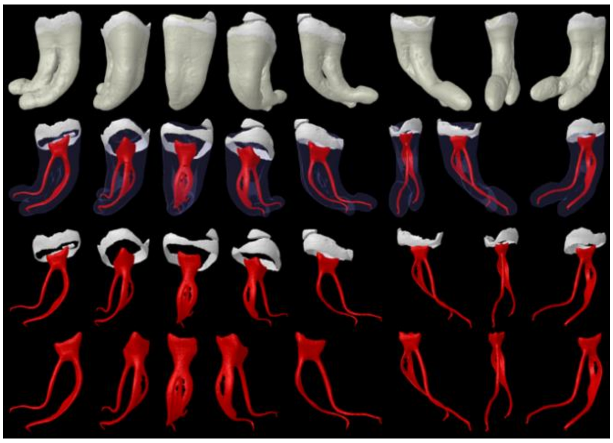
In recent years, imaging techniques have been used for scientific purposes as well as for diagnostic purposes in the course of technological development. Revolutionary possibilities were presented for scientific research within the functional principles of Micro CT, image quality and three-dimensional reconstruction. Many morphological analysis performed by conventional histomorphological methods can also be performed using Micro CT. With a voxel size nearly one million times smaller in volume than computed tomography (CT), the voxel size of Micro-CT is between 1 and 50 µm. Thanks to this small voxel size, Micro-CTs offer excellent cross-sectional resolution. Micro-CT is currently used in a variety of fields including biomedical research, materials science, development and manufacturing of pharmaceutical medicine, composites, dental research, electronic components, geology, zoology, botany, building materials and papermaking. Micro-computed tomography allows the direct examination of mineralized tissues such as teeth and bones, ceramics, polymers and biomaterials. In reviewing recent studies in dentistry, numerous studies have been observed with concepts such as evaluation of root canal morphology, evaluation of root canal formation, assessment of root canal filling, examination of remaining obturating material after root canal treatment, craniofacial bone development, and measurement the melt thickness could be found in the literature. In addition, microcomputed tomography is used as a non-destructive, fast and reliable method for the imaging of microarchitectures of cortical and trabecular bone. In addition, microcomputed tomography is used as a non-destructive, fast and reliable method for the imaging of microarchitectures of cortical and trabecular bone. Taking advantage of all these advantages offered by microcomputer tomography, several studies could be undertaken to shed light on clinical research in the field of dentistry. Tooth or bone samples can be reconstructed in 3D, allowing printing.



OP-18. PERSONALIZED MEDICINE: A MACHINE LEARNING APPROACH TO INVESTIGATE POSSIBLE NETWORK STRUCTURE OF LUNG CANCER FOR TARGETING CANCER SPECIFIC PATHWAYS

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Introduction

Cancer is a leading cause of mortality worldwide, reporting approximately 9.6 million deaths in 2018 and the most common type is lung cancer with 2.09 million case[1]. Omics profiles in lung cancers have not been comprehensively deciphered yet. Genomic Data Commons (GDC) provides wide information landscape of genomic and epigenomic alterations, accounting 2932 adenoma and adenocarcinoma cases[2]. This massive amount of data may help us to shed light on interactions among the driver genes in terms of the network profiling. Recent studies show promising results on system and network based modelling approaches to personalized cancer medicine[3,4].

Methods

In this study, gene expression data for Lung Adenoma and Adenocarcinoma (LUAD) gathered from GDC data portal. Mutations are encoded according to their presence or absence to cope with structure learning problem of ancestral history of possible network interpretation. Unnecessary and redundant information was pruned from data with the association rules by investigating togetherness of mutations due to cumulative nature of cancer. Remaining data sorted into pairs in terms of to their prevalence. Several scoring algorithms (Bayesian Information Criterion, Akaike Information Criterion and K2) used to evaluate possible network models. By utilizing this information Bayesian networks were created showing the possible interaction network for LUAD. Finally, results were compared with Online Mendelian Inheritance in Man (OMIM) database. R v3.14 statistical programming language and arules, bnlearn and Rgrapviz packages were used for the analysis.

Results and Discussion

According to our study, we have found several possible networks structures based on different algorithms. AIC and BIC gave linear results. However, K2 methods gave complex network structure and not only gene to gene but also genes to gene interactions were observed. K2 network represents the possible interactions better than AIC and BIC by comparing the pairwise interactions with OMIM database.

Conclusion

These network structures indicates different perspectives to mutation timing and LUAD progress by using recurrency information. Our results can gave a predictive power to decipher relational background of mutation interactions for developing oncological drugs to target certain pathways. We believe that by combining with the recent 3D drug printing technologies precision and personalized medicine concepts may give rise to prolong patients' survival times. Our methods alone may not give perfect accuracy but it can give us an intuitive approach to find out what is unseen yet.

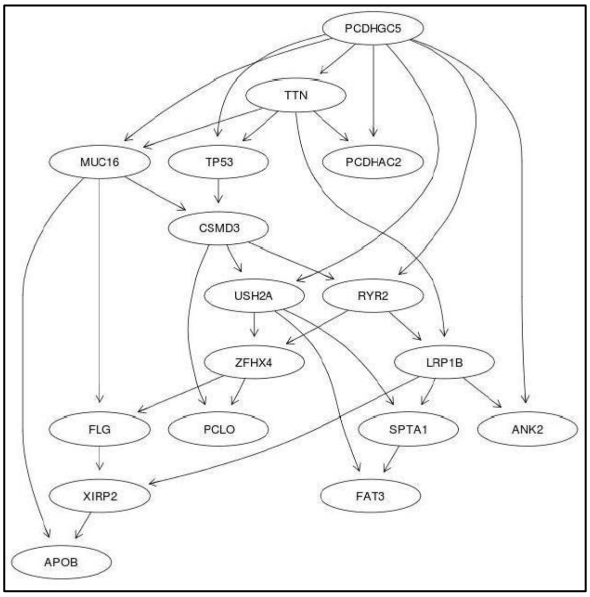

Figure 1. Inferred Bayesian network model for LUAD.

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OP-19. CLINICAL APPLICATIONS OF OSTEOPORE REGENERATIVE TECHNOLOGY

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Introduction

Osteopore International is a Singapore medical device manufacturer of biomimetic implants that are able to empower natural tissue regeneration. To date, we have more than 10,000 successful implants in patients globally, with more than 10 years of clinical follow-up. Our areas of application include reconstruction of cranio-maxillofacial and orthopaedic long bone defects. In this presentation, we would like to present unique clinical applications of our products in these areas, and demonstrate the impact that our technology has provided to healthcare stakeholders.

Method

To realize the concept of Tissue Engineering clinically, Osteopore has clinically combined the following key components: scaffold, cells, and growth factors. Osteopore utilizes 3D printing to achieve a biomimetic scaffold microstructure that has been evaluated to result in tissue regeneration and vascular infiltration. The open pore structure facilitates inoculation of cells and growth factors, which is obtained from the same patient (autologous), to enhance healing. We present results of the following three clinical applications: adult cranioplasty, paediatric cranioplasty, orthopaedic segmental bone defect reconstruction. Outpatient follow-up and medical images were used to evaluate the clinical effectiveness of the implants.

Results

A Patient Specific Implant (PSI) was designed and manufactured for a patient with a large cranial defect (97x80mm). Bone marrow aspirate was used in this case, and CT scans at 8 months demonstrated complete tissue coverage. In another case, a young patient suffered from incomplete bone growth in the calvarium. A PSI was designed and implanted together with a periosteal flap that was surgically rotated onto the implant. CT scans at 6 months showed clear bone formation – the reconstructed bone was maintained until 24 months without evidence of resorption.

In orthopaedic surgery, a patient suffered 150mm of bone loss in the tibia due to a tumour resection. A PSI was designed and combined with reamed bone and bone marrow aspirate. 4 months post-operatively, the patient was able to ambulate unassisted, and CT scans at 6 months showed complete bone bridging across the 150mm defect.

Conclusions

The results from our clinical collection provide convincing evidence that Osteopore's regenerative technology is able to realize the concept of Tissue Engineering and Regenerative Medicine in clinics.

OP-20. MICROEXTRUSION APPLIED THREE DIMENSIONAL (3D) BIOFABRICATION OF ENDOTHELIALIZED MYOCARD TISSUE

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Introduction

Cardiovascular diseases represent the leading causes of worldwide morbidity and mortality. These diseses causes death of more than 20 million people annually. More than 600,000 cardiovascular surgical interventions are performed every year and this costs around 200 billion dollars. The most prevalent cardiovascular diseases are heart tissue diseases which cause heart attack. One of the most prominent solution for this problem is to develop heart valves and heart tissues that are fabricated by 3D organ biofabrication methodologies such as bioprinters. The purpose of this research is; to fabricate endothelial myocard tissues that have high durability and high biocompatibility by the help of microextrusion techniques. Microextrusion has proven potential for fabricating 3D models with high biocompatibility and structural integrity. In this study, this purpose is aimed to be succeeded and analyzed detailed biocompatibility characteristics of fabricated multilayered heart tissue.

Methods

Preperation of PEGDA: GelMA Mixture

PEGDA (Polyethylene Glycol Diacrylate: Type A:Mn 700) is obtained from Sigma-Aldrich and dilluted 30%. 0.5% photoinitiator is prepared and mixed with dilluted PEGDA.

In order to prepare GelMA 10 g gelatin, 8 mL methacrylic anhydride and 100 mL PBS was mixed. The solution was mixed for 3 hours around 50°C. Then, mild PBS (40°C) was mixed with the solution. Finally the solution was mixed for one week around 40°C. Finally it was lyophilized.

As a bioprinter a modified Lulzbot TAZ 5 was utilized.

Results and Discussion

Cardiac Fibroblast Cells (NIH-3T3) were cultured with DMEM, 10% (v/v) FBS, 5% CO_2 under atmospheric pressure at 37°C. Cell media is changed in every three days due to long incubation periods. An inverted Zeiss Axio microscobe is used for cell viability, cell proliferation and DAPI/ACTIN analysis.

As a result more than 70% cell viability is observed in cell viability even after 7 days. Cell proliferation and DAPI/ACTIN results were satisfactory enough.

Conclusion

The fabricated tissue may easily be utilized for drug development studies and drug toxicity researches. Unfortunately there is still a long way to go for clinical trials.

OP-21. DIMENSIONAL ACCURACY AND PULL-OUT PERFORMANCE OF 3D PRINTED VERTEBRA MODELS

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Introduction

Three-dimensional (3D) printing technology is one of the technologies that has the potential of facilitating and transforming our lives and is becoming increasingly widespread nowadays. 3D production methods help of the surgeon to examine the complex anatomy of the spine in every aspect, in Neurosurgeon and especially in spine surgery[1]. The education of residents is provided by cadavers, animals and standard models, but these are expensive or insufficient for education[2]. The main aim of this study is to produce physical simulations on human-like vertebra bone structure (cortical and trabecular regions) and to provide screwing procedure training to residents by using these 3D vertebrae models. For this purpose, the effect of material selection, printer parameters was evaluated on 3D printed models in terms of accuracy of the models and understanding of complexity of treatments by comparing with 3D image methods.

Methods

A preliminary study was performed on the human L3 vertebra. The human L3 vertebrae obtained from the anatomy department has scanned with a photogrammetry method (3D scanner) and the scan data was converted to stl (standard tessellation language) format and transferred to the Geomagic program for the development of the model before transfer to the slicer program. Afterwards, printing parameters have been set in the slicer program of Cura. The parameter of infill density (30, 35 and 40%) and thermoplastic filament types (PLA and PC) were determined for the production of vertebrae models. A FDM (Fused Deposition Manufacturing) type of 3D printer (Ultimaker 3) was used in this study. Each vertebra model was screwed with a pedicle screw (diameter of 6 mm and 50 mm in length) for pull-out strength measurement. The pedicle screws extracted using MTS testing machine. The screw pull-out rate was 5 mm/min.

Results and Discussion

As seen in the table, it was determined that the same type of printer was used, but the screwing resistance of the model vertebra according to the filling density and the raw material and the screw holding resistance of these models were presented in Table 1. Increasing infill density increased the pull-out strength of both PLA and PC vertebra models. Moreover, the 3d vertebral body of model showed high dimensional similarity with the cadaver vertebra.

Table 1: Weight and pull-out strength of vertebra models

Material	Infill Density (%)	Vertebra Weight (gr)	Pull-out Strength [N]
Cadaver	–	12,15	–
PLA	30	14,38	236
PLA	35	16,04	379
PLA	40	16,76	389
PC	30	20,81	1033
PC	35	22,05	1205
PC	40	22,4	1530

Conclusion

In the first time, the pull-out strength of L3 vertebra was applied on replicated 3d vertebral body model which printed in high dimensional accuracy based on scanning data of human cadaver. The results showed that infill density and material types significantly affect the pull-out performance. The physician consideration procedure was evaluated during screwing on vertebra models and their consideration on screwing on the vertebra models made with PLA and infill density of 30% and 35% that is comfortable processing similar to real human L3 vertebra body.

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OP-22. DEVELOPING 3D PRINTED SCAFFOLD MASTERS FOR MICROFLUIDIC BIOREACTORS

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Introduction

Tissue engineering aims to design, reconstruct and control new tissue models and organs artificially, to help current medical treatment tools by accelerating the healing process of the body and overcome limited availability and inherent complications of tissue and organ transplants[1]. Bone tissue is the most commonly transplanted tissue after blood and has significant effect on the quality of life. Due to the prolonged life expectancy and an aging world population, there is a significant increase in musculoskeletal pathologies such as fractures, low back pain, scoliosis, osteoporosis, bone infection or tumours, osteoarthritis, congenital defects, oral and maxillofacial pathologies. Although bone transplantation having been used for over a decade in the clinical setting, bone grafts display some disadvantages such as supply limitation, risk of morbidity and high rate of failure which limit their applications in therapy. In the last decades, tissue engineering and regenerative medicine have emerged as promising strategies for bone reconstitution[2]. Commonly, a 3-D structured scaffold is utilized for tissue construction where cells are statically cultured. Static cell culture fails to mimic many biologically significant processes and hence is not suitable for tissue construction. By combining microfluidic platforms and 3D ceramic scaffold manufacturing techniques, a rapid, cost-effective and reproduceable solution for tissue/organ damage and drug discovery emerges[3].

Methods

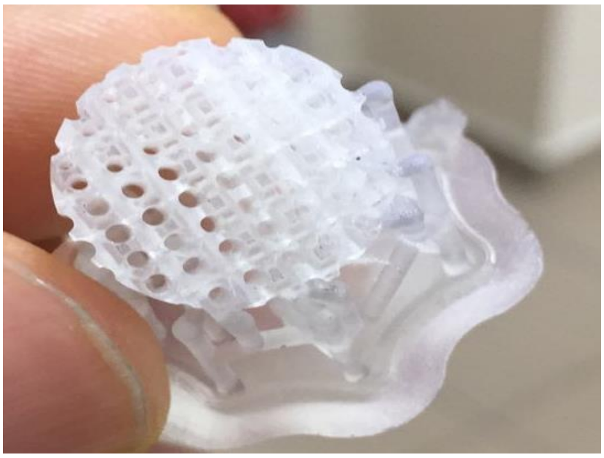
Hydroxyapatite based ceramic scaffold was manufactured by using a 3D printed (Form2, Formlabs) acrylic based polymer master from CAD model. The master was then filled with fine ceramic powder and sintered. After sintering, the polymer master evaporated and ceramic scaffold was obtained. In order to prevent any phase change in the ceramic XRD analysis was carried out and sintering temperature was adjusted. Moreover, porosity, pore size and architecture of scaffolds were observed with microCT and SEM analysis.

Results and Discussion

Results suggested that the polymer matrix design did not have sufficient resolution and integrated porosity to support the mechanical properties after sintering. Following the sintering process ceramic scaffold had almost no mechanical stability to hold the integrity of the structure. Therefore, it is suggested that the CAD model should be adjusted for further experimentation.

Conclusion

Indirect 3D printing of scaffolds for microfluidic bioreactors provides an alternative for bone graft applications and drug discovery by enabling experimentation on human cells in a 3D setting rather than conventional methods such as animal testing. Utilization of such dynamic, rapid, cost-effective and easy-to-produce systems provides an attractive solution for industrial processes as well as research purposes in many fields including regenerative medicine, tissue engineering and biomaterial development. 3D printing is a promising technique for 3D ceramic scaffolds with complex structure that provide sophisticated regenerative medicine solutions.



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Acknowledgements

This work was supported by TUBITAK 2209-B Industrial Based Undergraduate Dissertation Program with project number 1139B411701444. 3D printer at Assist. Prof. Dr. Cumhur Tekin Lab (IzTech) has been utilized at this work. Ceramic powder was provided by BoneGraft Biyolojik Malzemeler-Izmir.

OP-23. THREE-DIMENSIONAL PRINTING STRATEGY TO FABRICATE MICROFLUIDIC DEVICES WITH ENHANCED OPTICAL TRANSPARENCY

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Introduction

Microfluidic devices can be fabricated using several different techniques, such as, soft lithography, micro-machining and hot embossing[1]. However, these techniques are costly and labour-intensive[2]. Alternatively, three-dimensional (3D) printing technology can be used for rapid and easy prototyping of microfluidic devices[3]. In this technology, the models are designed by computer aided design program (CAD) and these digital models are directly transformed to physical models by simply printing[4]. However, optical transparency of printed structures does not allow visualization of microparticles or cells inside microfluidic channels for life-science applications[5]. Here, we presented a new method to fabricate transparent microfluidic devices by combining 3D printing technology with a bonding strategy.

Methods

After designing 3D models of microfluidic devices (Figure 1) having 600 µm width × 600 µm height × 12000 µm length using CAD, the models were printed using Formlabs Form 2 desktop stereolithography 3D printer. We used two different approaches to fabricate microfluidic devices. In the first approach (Figure 1A), microfluidic device was fully fabricated using 3D printer. In the second approach (Figure 1B), a 3D-printed structure and a glass slide freshly coated with polydimethylsiloxane (PDMS) were assembled together and then bonded to each other by baking at 80 ºC for 12h. Before this process, the glass slide was cleaned with ethanol, treated with 100W O2 plasma at 0.5 mbar for 2 minutes, and coated with 10:1 PDMS mixture at 2000 rpm for 25 sec, respectively. To test the optical transparency, red food dye (RFD) and 10-20 µm diameter fluorescent green microspheres (FGMs) were injected to microfluidic channels. The channels were inspected under Axio Vert A1 inverted fluorescent microscope.

Results and Discussion

After RFD was injected to the microfluidic channel, sharper microfluidic channel borders were clearly observed in the microfluidic device fabricated using the second approach (Figure 2A,C). Moreover, only in the microfluidic device fabricated using the second approach, FGMs could be imaged under fluorescence microscopy (Figure 2B,D). According to these results, the second approach to fabricate microfluidic devices showed better optical transparency than the traditional 3D printing approach.

Conclusion

We presented a new fabrication strategy where 3D printed part was bonded to a glass slide to make monolithic microfluidic devices. This strategy could offer new opportunities in rapid prototyping of microfluidic devices by enhancing optical transparency of microfluidic channels, and thus allowing brightfield and fluorescence imaging of micro-objects.

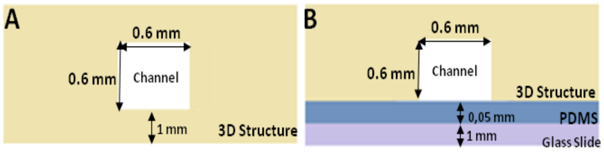

Figure 1. Cross sectional views of microfluidic channels fabricated using (A) first and (B) second approaches.

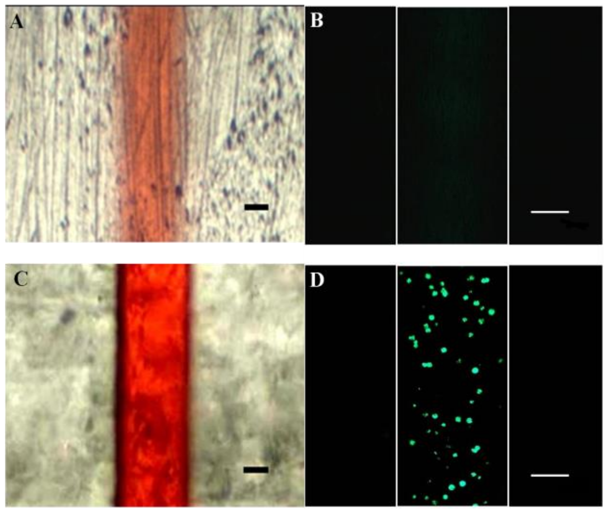

Figure 2. Micrographs of microfluidic channels using (A, B) first and (C, D) second fabrication approaches. Channels were filled with (A, C) RFD and (B,D) FGMs. (A,C) Brightfield and (B,D) fluorescence microscopy were used for imaging. Scale bars are 200 µm.

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Acknowledgements

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OP-24. 3D PRINTING OF ELASTOMERIC BIOMATERIALS

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Introduction

A key challenge towards engineering 3D printed soft tissues is the availability of proper scaffolding materials with enough load carrying capacity[1,2]. In this study, we synthesized biocompatible and biodegradable, elastomeric polyurethaneureas (TPUU) and investigated the applicability of these novel materials as 3D printed load carrying constructs.

Methods

Materials: Polycaprolactone glycol, amine terminated polyethyleneoxide, 1,6-hexamethyl ene diisocyanate, dibutyltindilaurate and tetra hydrofuran were used for polymer synthesis.

Synthetic Procedure: Reactions were conducted in 100 mL Pyrex flasks, fitted with an overhead stirrer, nitrogen inlet and addition funnel. Calculated amounts of PCL and HDI were introduced into the reactor and dissolved in THF to obtain a 30% by weight solution. 100 ppm T-12 (1% solution in THF) was added and the system was heated to reflux. Reactions were completed in about 2 hours. Solution was cooled down to room temperature, stoichiometric amount of PEO was dissolved in THF and added into the reaction mixture dropwise through the addition funnel. Progress and completion of the reactions were monitored by FTIR spectroscopy[3].

3D Print Procedure: Polymers were then 3D printed on an Envisiontech 3D Bioplotter system either in molten state using high temperature print heads or in solution form with low temperature print heads in dichloro methane with various concentrations (70-140% w/v). 3D prints were done in simple cylindrical architecture. Structural and mechanical properties of scaffolds were determined using SEM and tensile tests (Schimadzu).

Results and Discussion

Compositions of polymers synthesized are provided in Table 1.

The polymers were 3D printable in their molten and solution states. Investigation of 10 layer prints revealed that while the prints have good structure, 70% solution prints exerted better elasticity (Figure 1, left panel). 3D printing of TPUU-3 in the solution form (70% w/v), on the other hand, showed good structural stability as well as elasticity (Figure 1, right panel).

Table 1. Chemical compositions of TPUUs in weight percent

Code	PCL	PEO	HDI
TPUU-1	91.6	--	8.40
TPUU-2	68.6	22.9 (2000)	8.50
TPUU-3	61.8	26.0 (600)	12.2

Conclusion

It was possible to 3D print elastic polyurethaneurea scaffolds with full recovery.

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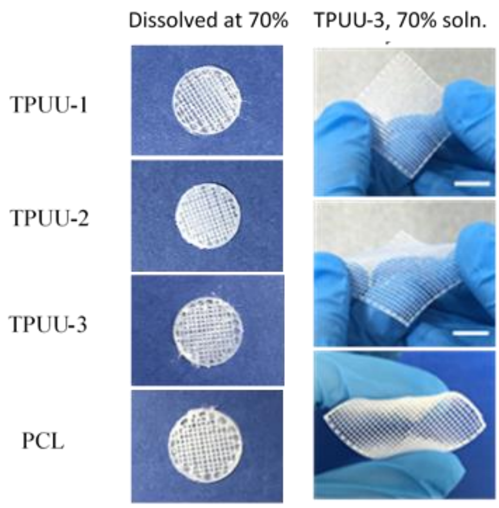

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OP-25. DEVELOPING AN ARTIFICIAL HUMAN AURICLE FABRICATED IN POLYURETHANE BY A FUSED DEPOSITION MODELLING (FDM) 3D PRINTER

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Introduction

3D printer technologies have brought significant innovations in various fields such as tissue engineering, artificial organ formation and advanced pharmaceutics due to their excellent features such as efficient fabrication speed, requires no harsh chemicals for production, provides improved feature resolution and cost efficiency[1,2,3]. In this work, we have developed an artificial human auricle by a FDM 3D printing technology.

Methods

We aimed at constructing an artificial human auricle by using an Ultimaker's 3D printer with FDM modelling. Schematic view of the FDM 3D printing setup used in this work was presented in Figure 1. The polyurethane (PU) having biocompatibility and flexibility was used to form the auricular scaffold for biomedical applications. Auricle samples produced at several infill rates were characterized by using physical tests (e.g.: polymer's contact-angle, viscosity, density and surface tension), mechanical tests, (e.g. hardness and tensile strength), SEM, XRD, FT-IR, and TGA techniques.

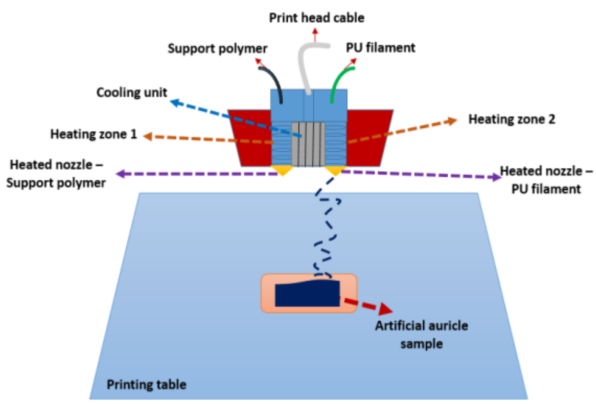

Fig. 1: Schematic representation of the artificial human auricle formation using an Ultimaker's FDM 3D printer.

Results and Discussion

The auricle samples produced of PU filament were presented in Figure 2. Hardness of the PU used was performed by using an

AMITTARI hardness tester. Resultant auricle samples hardness value was indicated as 50 (Shore D). FT-IR measurements of the filament used was carried out by using a Bruker TENSOR 37 FT-IR Spectrometer. FT-IR characteristic peaks of the PU polymer filament used was observed as indicated in Figure 3 at varying abundance rates in the range of 500 to 4000 cm-1 wavenumbers. It can be clearly seen that the characteristic peaks map of PU were obtained.

Conclusion

Artificial human auricle samples were successfully produced and improved at several infill rates (e.g.: 25%, 50%, 75%, and 100%) of PU filament using a FDM 3D printer.

Fig. 2: TPU auricle samples achieved at several polymer filament's infill rates. (a) 25%, (b) 50%, (c) 75%, and (d) 100%.

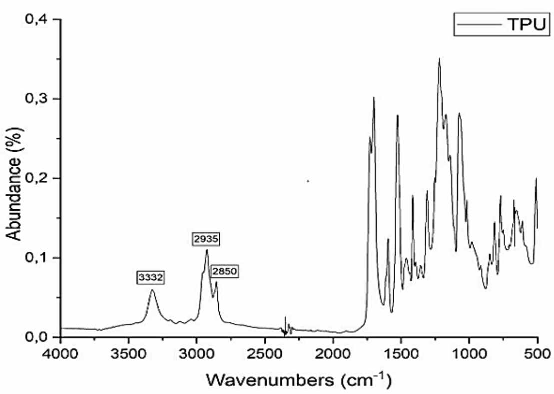

Fig.3: FT-IR characteristic peaks of the polymer used in this experimental work.

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OP-26. PLACENTAL MEMBRANE MESENCHYMAL STEM CELL CULTURE IN 3-DIMENSIONAL PRINTED SCAFFOLD: PRELIMINARY RESULTS

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Introduction

Recent advances in 3-dimentional (3D) modeling and printing technologies have created new opportunities to
Investigate cell proliferation, viability and differentiation in biologically relevant microenvironments[1,2,3]. Therefore, tissue engineering and functional organ bio-printing using biocompatible and biodegradable biomaterials are getting extensive research areas in the field of regenerative medicine[4]. In this context, poly lactic acid (PLA) scaffold with its low interactions with biological structures is proposed to be a suitable biomaterial for extracellular matrix[1,2,3,4,5,6]. In this study, we aimed to investigate the effects of 3D PLA printed scaffolds on proliferation, viability and surface antigens of the cultured placental membrane mesenchymal stem cells (MSCs).

Methods

Different 3D scaffold designs were prepared Autodesk Fusion 360 and the lattice structures were generated by nTopology Element. Then, converted into 3D printer format by Ideamaker software and manufactured in 3D printer (Raise 3D N2, Irvine, CA, USA) using industrial-grade PLA flament1.The main differences included 3D structures, pore sizes, and porosities. The mesenchymal stem cells, originated from placenta, cultured in T-25 flasks and incubated in CO2 incubator. On the fourth day of the cell culture, EO sterilized 3D printed scaffolds were put into the flasks (except control group). On the tenth day, the control group was trypsinized. PLA materials were taken out and trypsinized in another tube. All groups were investigated by means of cell count, viability and surface antigens characteristics of the cultured cells.

Results and Discussion

As it is in the control group MSCs with fibroblastic character were observed inside the PLA pores while examining by inverted microscope during cell culture process. Cell counts in flasks showed no significant differences compared to control group however, cell proliferation differences were related with the PLA scaffold porosities. The cultured cells obtained after trypsinisation from PLA scaffolds have viability of 95% and have same surface antigens as the control group: CD45 and CD34 antigens were negative while CD73and NG2 antigens were positive.

Conclusion

Recently, there is increasing number of studies on MSCs originated from placental membrane in the literature7. It can be easily obtained by non-invasive methods. It is believed that these cells will be one of the main choices of tissue engineering in the future. According to our literature review so far we have not found any study on cell culture of MSCs originated from placental membrane using 3D printed PLA scaffold. The preliminary results of this study suggest that PLA scaffolds did not inhibit proliferation of the MSC. Moreover, on this material MSCs can proliferate without any impact on their viability and surface antigens. Therefore, we believe that PLA will be a solution for creating scaffold for MSCs which will be a breakthrough in regenerative medicine.

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OP-27. 3-DIMENSIONAL MODELLING AND COMPUTATIONAL FLUID DYNAMICS EXPERIMENTS ON UPPER AIRWAY OBSTRUCTION SURGERIES

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Introduction
Upper airway obstruction contains a wide spectrum of diseases from mild nasal clogging to major life-threatening dyspnea. Without understanding the normal function of the glottis in breathing, treating dyspnea does not restore normal physiology.

Methods
We designed a computational fluid dynamics (CFD) model that tested the respiratory cycle in larynges with normal glottis and congenital glottic web (CGW). A CGW case and a control subject (CC) were selected from the computed tomography (CT) archive. 3D computational models of the larynges with structured boundary layer were constructed from axial CT images after mesh refinement study. CFD analyses were based on the Reynolds-averaged Navier–Stokes approach. Incompressible flow solver (pressure-based) and SST k w turbulence model were chosen for this study. To simulate a real-time breathing process, time varying flow rate boundary condition was derived from the spirometer of a healthy, non-smoking woman

Results and Discussion
Glottic areas were measured as 51.64 and 125.43 mm^2 for the CGW patient and CC,respectively. Time dependent velocity contours and streamlines for the CC and CGW patient were drawn. The CC showed uniform flow, all through the inspiration and expiration phases. However, the CGW patient showed separation of flow at the glottis level, which caused areas of stagnation in the supraglottis (during expiration) and the subglottis and trachea (during inspiration). Specialized geometry of the normal larynx maintained uniform flow with low shear stress values on the wall even at high mass flow rates.

Conclusion
Distortion of this geometry may cause obstruction of flow at multiple levels and, therefore, should be evaluated at multiple levels. Patient-specific models may help in evaluation and treatment planning.

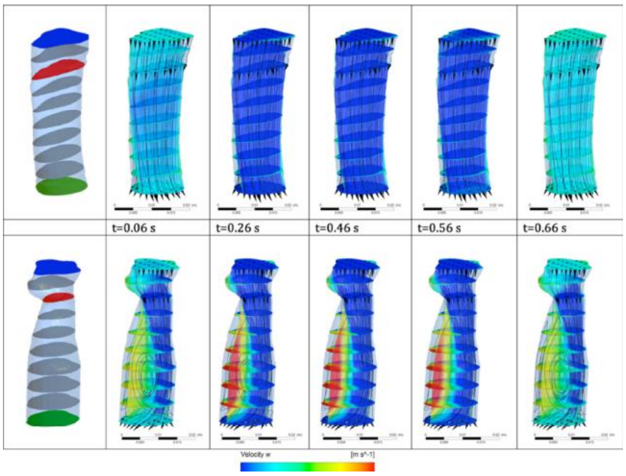

Figure 1. Velocity contours and streamlines during inspiration phase for control case (CC; first row) and patient with congenital glottic web (CGW; second row)

OP-28. THE ROLE OF 3D PRINTING TECHNOLOGY IN CONTEMPORARY ORAL AND MAXILLOFACIAL SURGERY

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Introduction
The past thirty years have seen the rapid development of three-dimensional (3D) printing technology in the field of medicine and especially oral and maxillofacial surgery (OMFS). This technology provides reproducible and precise patient-specific models for use in various reconstruction, rehabilitation and regeneration surgeries. Contemporary use of 3D surgical models in maxillofacial surgery include harvesting bone grafts, cutting guides for osteotomies, tissue engineering, temporomandibular joint reconstruction and correction of facial asymmetry. This study aimed to evaluate the latest updates, benefits and limitations of 3D printing technology in the oral and maxillofacial region.

Methods
A literature review was conducted using the medical databases Ovid/MEDLINE and PubMed/EMBASE to explore the current applications of 3D printing in the field of OMFS.

Results and Discussion
The main use within maxillofacial surgery included surgical planning, trauma surgery, dental implants, facial prosthetics, orthognathic surgery, facial reconstruction, TMJ reconstruction and surgical and patient education.

Conclusion
Despite several limitations such as high cost and time-consuming process of development, use of 3D printing technology in OMFS seems to provide promising results. Recent trends have heightened the need for more research to improve the existing 3D printing techniques.

OP-29. COMPARISON OF PRE-OPERATIVE SURGICAL PLANNING SOFTWARES FOR MANDIBLE RECONSTRUCTION

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Introduction
Reconstruction of the mandible using autologous tissues is an important practice in reconstructive microsurgery. Without virtual surgical planning reconstructive plates are intra-operatively shaped to fit into the patient’s new mandibular structure. Osseous component of the fibula free flap and fixation plates must be reshaped during the operation by trial and error, which is often a time-consuming procedure. As a result, more time is spent in the operating room and plates may be worn out due to overbending. Pre-operative surgical planning helps overcome these problems. 3D printing of the mandible and accessory bending plates and surgical guides is performed either by commercial or open-source software. The majority of the clinical practices and publications about 3D mandibular modeling uses highly expensive commercial software and they are considered to be the golden standard of virtual surgical planning. The aim of this study is to compare free and paid software for virtual reconstruction of the mandible.

Methods
CT imaging studies with a matrix of 512x512 pixels each and a slice thickness of 1.25 mm were retrieved from the server at the Radiology Department of Ankara University School of Medicine. The CT data were analyzed, and the 3D models of mandible were reconstructed using Materialise Mimics (Materialise NV,

Belgium), MITK software (German Cancer Research Center, Germany), 3D Slicer (www.slicer.org), MIPAV (Center for Information Technology, USA), ITK-Snap (http://www.itksnap.org) and InVaselius (Centro de Pesquisas Renato Archer, Brazil) programs. Both virtual 3D models were converted to STL format and exported to another set of commercial and open-source softwares, 3Matic (Materialise NV, Belgium), MeshLab (Consiglio Nazionale delle Ricerche, Italy), for image and morphometric analyses respectively. The measurements of themandibles were recorded using gnathion, infradentale,mental foramen, mandibular crest, inferior mandibular border and condyles as reference points. The Hausdorff distance between mandibular models were evaluated to assess geometric differences between models.

Results and Discussion

The measurements of the mandibles were compared using a Wilcoxon signed rank test and the error rates of the Hausdorff distance were documented. The 3D models of the mandible produced using corresponding softwares showed no significant differences.

Conclusion

Pre-operative planning can be made by free, open-source software to minimize the operational cost. There are several online tutorials and a strong on-line community to ease the learning curve of open-source software.

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OP-30. USE OF 3D PRINTING IN ORTHOPAEDIC SURGERY: AN ANALYSIS OF LITERATURE FOR THE LAST 3 YEARS

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Introduction

Use of three-dimensional (3D) printing is a technique based on overlapping layers of materials such as plastic, clay and metal. The use of 3D printing in orthopaedic surgery is increasing due to its benefits such as decreasing complication rate, surgical time, and the damage of tissues and the time for recovery. Here, we try to evalute the literature for the last three years to determine the use of 3D printing in orthopaedic surgery.

Methods

A literature search was performed for extracting papers that are written in English and related to 3D Printing in orthopaedics surgery from the Pubmed between 2015-2018. We searched with using suitable key terms "3D Printing" or "3 dimensional printing" or "3D printed" or "additive manufacturing" and "Orthopaedics’’. Papers related to orthopaedic surgery were manually selected for this review. Fifty-eight articles and case reports were evaluated.

Results and Discussion

3D printing is used for planning surgery and reconstruction in trauma, tumor and reconstructive surgeries. Applications used in different body parts such as lower and upper limbs, vertebral structures, shoulders, hips and pelvis. 3D printing is mostly use in orthopaedic traumas for planning the surgey. Scoliosis, primer and metastatic cervical tumors are widely planned by using 3D printing in vertebrae. Pelvic and hip fractures especially acetabulum fractures and tumors are the second areas which 3D printing is used.

Reports about using in wrist, hand and foot are very rare. The review of literature showed that surgical strategies are improved and complication rates were decresed if surgery combined with 3D printing use to produce custom made prosthesis. 3D printing allow to evaluate the surgeon to evaluate the different approach alternatives and establish the best strategy.

Conclusion

3D printing seems very useful in ortohopaedic surgery but double blinded, randomized studies are required to support these findings.

OP-31. USING OF 3D PRINTED HIP JOINT MODEL IN PRESURGICAL PLANNING OF ARTHROPLASTY FOR A PATIENT WITH CONGENITAL HIP DISLOCATION: A PILOT STUDY

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Introduction

Total hip replacement is challenging in cases of osteoarthritis secondary to developmental dysplasia of the hip. Acetabular deficiency and femoral deformities make the templating of the acetabular and femoral components difficult with traditional molding methods.

Material and Methods

A patient (40 y.o., female) with osteoarthritis after congenital hip dislocation was examined for the total hip arthroplasty. Dicom images of the hip joint obtained by computed tomography scanning were 3D reconstracted and printed.

Results and Discussion

Patient-individual 3D printed PLA models were used to plan the placement of acetabular cup and femoral stem so that a surgeon was able to identify pelvic and femoral structures, assess the ideal extent of reaming and determine the size of cup and stem after a reconstructive procedure. We applied the total hip replacement components on the 3D model and found the appropriate acetabular cup and femoral stems. The acetabular cup and femoral stem sizes used in the patient's operation were the same as those detected in the 3D model.

Conclusion

The use of the 3D printing model facilitates the surgical procedures due to better planning and improved orientation.

OP-32. AUGMENTED REALITY ASSISTED CEREBROVASCULAR MICROSURGERY USING HAND-HELD COMPUTER DEVICES

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Introduction

Correct and complete preoperative radiological evaluation of patients with cerebrovascular pathologies carries a high importance for good surgical outcomes. Advances in neuroradiology and computer technology bring numerous alternatives to the neurosurgeons for surgical planning of these complex pathologies.[1,2] Recently, augmented reality techniques and systems are preferred and used in various industrial, technologic, medical sectors. Here, we present our simple and effective augmented reality technique in the surgical planning and perioperative management of intracranial vascular lesions.

Methods

Eleven patients operated due to supratentorial vascular Pathologies (3 AVMs, 8 Aneurysms) in 2017-2018 were included in our study. Thin slices computed tomography angiography images and magnetic resonance angiography images were obtained preoperatively and processed using free Osirix software. The reformatted 3-dimensional images were saved as ".stl" files and transferred to free AR software. Later, these images were uploaded to the hand-held computer devices. The AR images and the patients were matched on the computer display. The anatomic location and the feeding arteries, as well as drainage veins of AVMs, and the projection and morphology of the aneurysms with surrounding structures were visualized. The craniotomy, skin incision, surgical strategy were planned and confirmed with neuronavigation system. The AR images were compared with the microscopic views and the similarity of the intraoperative images with AR images was studied.

Results and Discussion

The data obtained from augmented reality technique matched with the data of the neuronavigation system. In 10 of 11 patients, the system showed correct position of the pathology. The feeding arteries and drainage veins were localized in the guidance of this method in a safer way. Additionally, the projections and the localizations of the aneurysms were coherent with the intraoperative observations.

Conclusion

Augmented reality techniques are newborn technology and developing day by day. Our technique is a simple, a fast and effective method for correct analyse and good surgical planning of intracranial AVMs and aneurysms.

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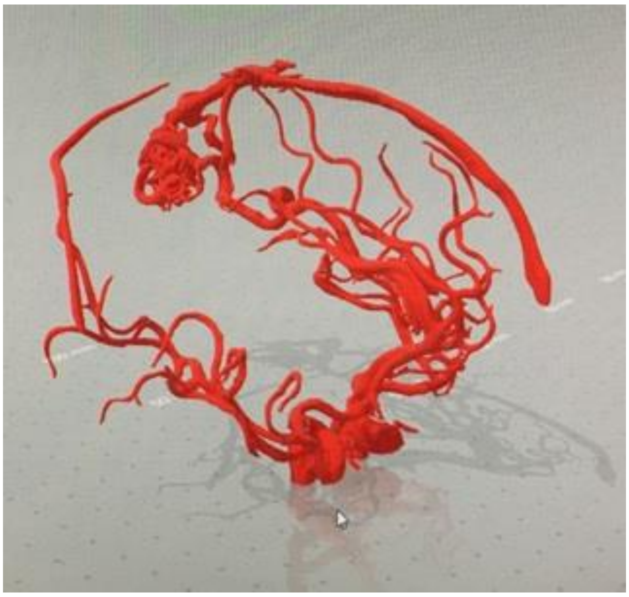

Figure. Surgical planning of intracranial AVMs and aneurysms with printed models

OP-33. THE EFFECTS OF 3D MODELLING AND ITS RELATED TECHNOLOGICAL MODALITIES (VIRTUAL, AUGMENTED AND MIXED REALITIES) AND 3D PRINTING IN ANATOMY CURRICULUM

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We need to add more student-centered applications, which facilitates teamwork and improve academic performance, to our Anatomy Curriculum because of traditional practical Anatomy education mainly depends on cadaveric dissection and usage of models composed of plastic or silicone. Recently, cadaver supply limitations and variable performance of model’s cost effectivity forced Anatomy educators benefit more from improved technologies like in every field of medical education.

With the technological achievements in late nineties, reconstruction and modelling softwares were developed to produce 3D anatomical models via processing radiological images. Then, real and identical models based on one to one its' production data (CT or MRI etc.) entered our educational life with the advantages of printing in 3D.

Modelling and printing of models started with hard tissues like bone which can be produced relatively easier from the sections. With the increasing number of developed softwares and hardwares, soft tissues like solid organs and neuro-vascular structures were also studied. Firstly, undergraduate educational videos and animations were prepared using these models. Later simulation models and simulators were improved for postgraduate surgical trainings including orthopedics, general surgery, urology, cardio-vascular surgery and otorhinolaryngology. During the technological development in early 2000's first virtual and augmented reality and then hybrid form of physical and virtual worlds via immersive technology, a.k.a. mixed reality were also applied efficiently to the anatomical models in these educational devices.

As a result, virtual and/or real 3D anatomical models and all these reality environments might be the most powerful supplementary and reinforcement option in both pre-clinical and clinical cadaveric Anatomy education for better understanding of the spatial locations and relations of the objects.

OP-34. USING 3D MODELING AND MANIFACTURING IN ANATOMY EDUCATION

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Introduction
Anatomical structure of human body does not change for hundred years. However the techniques used in anatomy education changes rapidly. The main aim of the anatomy education is not only to make the students familiar with the morphological structure of human body but to use their knowledge in clinical practice. So to cognize human anatomy in three dimensional manner and to evaluate variations are important for the medical students. Anatomical models are now widely used in preclinical and clinical training and even surgical planning. However anatomical variations could only be observed if they exist in the cadaver on whom the student makes the dissection in the lab. 3D modeling in anatomy education not only helps the students to understand the location of an anatomical structure in the body and its relations with the other structures, but makes them familiar with radiological images and sectional anatomy.[1] Using 3D modeling techniques will certainly increase the mental rotation ability of the students and increase their academical success. On the other hand in clinical use 3D models created specific for the patient will reduce the risk of surgical interventions.[2]
In the present study it is aimed to create a 3D model of thoracic aorta together with esophagus and to determine the relationship between these two anatomical structures in mediastinum.

Method
An anonymous chest MR images available from the Department of Radiology of Başkent University Medical Faculty were used. The software "TT3D-BMMP" uses two-dimensional patient dataset, segments the selected anatomical structure then generates surface mesh structure in a universal format of "msh". Segmentation is performed by an automatic algorithm with manual correction option. Post-processing options such as rendering and visualizations may be performed in any programs with post-processor option.[3]

Results and Discussion

A 3D Anatomy model production platform has been established. In the following studies 3D modeling will be done by the interactive collaboration of the students and their medical rotation abilities will be evaluated.

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OP-35. INVESTIGATION OF VARIATIONS OF RENAL VESSELS WITH THREE DIMENSIONAL MODELING

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Introduction

Three-dimensional (3D) printing is a technology that is developed rapidly in recent years. 3D surgical or anatomic models can be generated through special printing devices[1]. With a detailed tactile 3D objects of an organ, physicians may be able to make better determinations and plans for surgical approaches[2-3]. The aim of study is to reveal the branching variations of the renal artery and renal veins in detailed three dimensional models, thus to prevent complications that may occur in kidney operations, especially in transplantation, to help surgeons by accelerating the process of illuminating the vascular anatomy of the donor and recipient site.

Methods

1. Images: A total of 19 high-contrast computerized tomography (CT) angiography cross-sectional images of 10 female and 9 male patients who were older than 18 years of age, had no abdominal masses and had not undergone a surgical operation involving the abdominal region were included in the study. Images obtained from the database of Radiology Department of Ankara University School of Medicine.
2. Segmentation and Modelling: Manuel segmentation and modelling of the kidneys, renal vessels along with origins (relating parts of abdominal aorta and inferior vena cava), and renal pelvis with proximal ureter were performed. The lengths and diameters of the renal arteries and veins were measured bilaterally. These parameters were compared between genders. Vessel variations were also noted. All evaluations, segmentations and modelling were accomplished in *Materialize Mimics Innovation Suite*™ software.
3. Statistics: *SPSS™ Version 11.5* package program was used to evaluate the data. Data were evaluated by t-test / Mann-Whitney test. p value of less than 0.05 was accepted for statistical significance.
4. 3D Printing: Variation patterns were produced with 3D printer in accordance with the digital models. All models were painted manually after printing.

Results and Discussion

No significant difference was found between female male genders in the right renal artery length, diameter of right renal artery, length of left renal artery, diameter of left renal artery, length of right renal vein, diameter of right renal vein, length of left renal vein (*p* values respectively: 0,955; 0,303; 0,489; 0,564). In two cases, unidentified vessels in radiology reports were identified by our 3D models. In our study, late confluence of veins (1 on the left, 11 on the right), early branching of the arteries (n = 13), retroaortic vein (n = 2), accessory retroaortic vein (n = 1), two or more accessory arteries and veins (n = 5) and polar artery (n = 1) variations were determined. These variations were shown in 4 different 3D printed models (Figure-1).

Conclusion

It is seen that 3D modelling provides better evaluation than conventional 2D images in which radiological reports are prepared. Therefore, it can be thought that 3D modelling will be a guide for surgical planning especially before the operation of cases with variations.

Figure-1: 3D printed models showing the different renal vessel variations.

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Acknowledgements

Images were assessed by the *Materialize Mimics Innovation Suite* ™ software provided within the scope of the Scientific Research Project (PN:17Ö0230001) in the Department of Anatomy.

OP-36. REAL VS. ARTIFICIAL: USING OF 3D PRINTED MATERIALS INSTEAD OF PLASTINATED SPECIMENS IN VETERINARY EDUCATION

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Introduction

Due to the direct effect of veterinary services to all living beings, efficiency of teaching and training in veterinary education has always been a prominent issue for the professionals in this field. Several different techniques and materials have been used for the different courses and practical lectures in veterinary medicine. Increasing of concerns on educational animal use opened up an opportunity for the alternative materials and more humane methods in last decades (1, 2). Although various of alternatives such as computer simulations or simulator materials, high quality videos, preserved specimens or models has been developed, cadavers are still major education materials for the various courses even fresh or fixated (1, 3). However, toxicity, durability and biological safety problems lead the researchers to find more durable and non-hazardous materials. Plastination is a modern preservation technique for all types of organic specimens in which tissue fluids are replaced by re-active polymers (4, 5). Plastinates are dry, non-toxic and very durable specimens that look more life-like (6). But, this technique is still very expensive and takes remarkable time to obtain final products. On the other hand, 3D printing technology is becoming cheaper day by day with the improvement in devices and imaging techniques (7).

Methods

Various researches based on the usage and efficiency of plastinated specimens and 3D printed models have been searched. The positive and negative properties of each materials have been determined and compiled for this article. Therefore, a comprehensive comparison of two education materials could be performed.

Results and Discussion

Plastination uses the real organs or bodies itself for the plastination process and plastinated specimens have a definite advantage to understand the real shape, position and other morphological features of the target organic structure. However, color and size is still an important problem for plastinates. 3D printed models can provide an accurate shape of the scanned organ. Even though the improvement in the consumables of 3D printers are really fascinating, to create a perfect elasticity for all types of tissues is a prominent issue for 3D models. Tactual and visual properties of those models can be misleading for students.

Conclusion

As a conclusion, there are still several advantages and disadvantages for these materials and combination of these models and specimens would be an convenient method for veterinary education.

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OP-37. 3D PRINTED SKULL MODELS FOR COMPARATIVE VETERINARY ANATOMY

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Introduction

Veterinary anatomy education is carried out comparatively between different species. Comparative anatomy education allows researchers to understand anatomical features according to phylogenetic relations and dissimilar lifestyles of species. Thanks to the development of technology, many scientists who research on computer-based educational resources have focused on the production and development of 3 dimensional (3D) anatomical models and have conducted research on their utilization in medical education.[2] 3D anatomical models have become an excellent alternative educational tool for medical students. Models help simplify and accurately understand the complex topographic and functional relationships of anatomic structures.[1] In this study, it was aimed to produce 3D printed skull models of the dog, cat and domestic pig in order to evaluate its usability in comparative anatomy education.

Methods

In the study, skulls belonging to dog, cat and pig were used. 2D images of the skulls obtained by CT method were stored in DICOM file format. After transferring the DICOM files to the computer, 3D images of the skulls were created using the 3D Slicer software (3D Slicer, GitHub, San Francisco) program. 3D skull models were recorded in ‘stl’ file format on computer. Then the ‘stl’ files were uploaded to the 3D printer. The printing process was basically carried out at x, y, z coordinates using PLA polymer.

Results and Discussion

3D skull models were produced and specific anatomical structures on models were well defined. 3D skull models of animals were examined comparatively. The morphological differences between the skulls were determined on 3D models.

Conclusion

It is thought that 3D skull samples obtained in the study can be actively used in veterinary anatomy undergraduate and postgraduate educations. Thanks to the 3D bone models, maceration process preferred frequently in the preparation of bone samples can be eliminated. It is also predicted that usage of cadaver will be reduced significantly by using 3D anatomy models in the veterinary anatomy education.

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OP-38. THE EFFICIENCY OF 3D PRINTED MODELS OF HYOID BONE FOR BETTER EDUCATION IN COMPARATIVE ANATOMY

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Introduction

Additive manufacturing, also known as three-dimensional (3D) printing, is bringing the technological breakthrough in many areas, such as engineering, art, education, and medicine. The most important features in bone models produced by 3D printing for anatomy education are that the bone has to contain anatomical structures and preserves the real form of the original structure[1, 2, 3, 4]. Two separate themes are described in this study. The first theme is to present a graphical 3D modeling approach of different hyoid bones and its structures. The second theme involves making 3D printing models of these bony structures and compared with original forms.

Methods

Different hyoid bones (human, horse, cattle, dog, cat, and pig) were used to produce 3D printing models. Hyoid bones were scanned with the multidetector computed tomography. 2D images were stored in DICOM and segmentation and post-processing of these images was performed. 3D reconstructed images of the hyoid bones were acquired with 3D slicer software (3D Slicer, GitHub, San Francisco). 3D models of the hyoid bones were recorded in ‘stl’ file format on the computer. These ‘stl’ images were then used to produce physical 3D printing models with the FDM printer and polylactic acid (PLA) polymer.

Results and Discussion

This study describes and compares the anatomical features of the bone, digital models and 3D printing models with each other. It was known that hyoid bones are very thin and fragile. For this reason, 3D printed models could be used for these characteristic bones. These 3D models were seen useful for anatomy education and hard to break compared to original bones. It could be rapidly produced by 3D printing technology for anatomy education into classrooms.

Conclusion

This study shows that durable, real-like bone specimens could be produced with a minimal equipment and manpower. Both produced 3D models and 3D reconstructed images can be used during veterinary anatomy education.

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OP-39. EXPECTATIONS OF MEDICAL FACULTY STUDENTS RELATED TO THE USAGE OF 3D PRINTINGS IN ANATOMY EDUCATION

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Introduction

In modern medical education, many sources are used to improve the clinical capabilities and competences of students. The acquisition and use of these resources has become a challenge for medical schools. One of the most important materials in this challenge is cadavers. But this is not only a financial process for medical educators/schools, but also a process involving ethical, cultural and legal problems. At this point, the opportunities provided by modern technology are of great importance for these educators. 3D printer products have entered this field quickly with high realities and detailed views. In this study, we aimed to determine the interest levels, expectations and awareness of the medical faculty students in the use of 3D printers in anatomy education.[1, 2, 3]

Methods

The questionnaire was applied to 195 students. The questionnaire used in the research consists of two parts. In the first part of the questionnaire, there are 21 expressions in the 5-point Likert scale used for the use of 3d printers in anatomy education. In the second part of the survey, there are questions about the demographic characteristics of the participants.

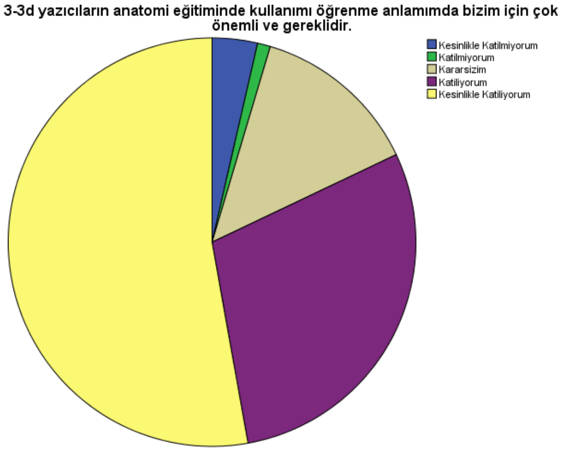
Results and Discussion

The reliability of the scale was determined as 0.911. Of the students participating in the study, 50.8% (99) were male student and 49.2% (96) were female student. 52.3% of the participants answered “I absolutely agree” with the question “I should definitely be taught about the use of 3D technology in medicine” in our faculty. 52.8% of the participants answered the question “I absolutely agree” with the question “The use of 3D printers in anatomy education is very important and necessary for us in terms of learning”. In addition, the results obtained from the independent sample t-test revealed that no significant difference was found by gender.

Conclusion

The answers of the participants indicate that although the students who have received anatomy training are unaware of the use of 3D printers in anatomy education, they think that it is beneficial to use them in the courses.

Figures



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POSTER PRESENTATIONS

PP-1. PREPARATION OF DEXAMETHASONE LOADED MICROPARTICLE COATED 3-D POLYMERIC SCAFFOLD FOR BONE REGENERATION

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Introduction

Bone regeneration is crucial for the treatment of some diseases that cause loss of bone mass, segmental bone defects, and fractures. Enhancing bone regeneration after bone disorders such as osteoporosis, osteoarthritis, osteomyelitis, and osteosarcoma remain a significant clinical challenge because of the difficulties in reaching therapeutic drug concentration at the damaged bone site. Therefore, localized controlled drug delivery systems have increasing importance in bone regeneration.1,2 Dexamethasone is a preferred drug for designing bone scaffold because of its unique properties such as osteogenic differentiation and anti-inflammatory effects.3 In this study, it is aimed to develop dexamethasone loaded microparticle coated three dimensional (3D) bone tissue scaffolds for regeneration of defected bone tissue.

Methods

<u>Preparation of DEX loaded PCL Microparticles</u>

Dexamethasone sodium phosphate (DEX) loaded Poly(Ɛ-Caprolactone) (PCL) (Mn: 45,000, Mn: 80,000) microparticles were prepared by emulsion formation-solvent evaporation method (W/O/W) according to the previous study.[4] Particle size and drug loading studies were carried out as *in vitro* characterization study.

<u>Fabrication of 3D PLA Tissue Scaffolds</u>

In this study, biodegradable polylactic acid (PLA) was chosen to design 3D scaffolds. As a production method computer-aided fused deposition modeling (FDM) approach was used to produce 3D bone scaffolds. To achieve that first, microarchitectural designed cylindrical poly-lactic acid (PLA) scaffold with defined morphologies (10 mm diameter and 1.6 mm in height) were designed by Sketchup (Trimble Inc., USA). Afterward, PLA filament was introduced to the 3D printer (Ultimaker 2+ (Ultimaker B.V., the Netherlands) which have 0.4 mm nozzle. Two different scaffold architecture in the form of rectangular and parallelogram honeycomb was fabricated. The fiber diameter and the pore size values were both 400 µm.

<u>Preparation of DEX Microparticles Coated Scaffolds</u>

50 mg of the DEX-microparticles were dispersed in 0.1 mL Na-alginate gel (2% w/v) and spread homogeneously on the surface of the scaffold with an injector. Then, DEX loaded microparticle containing alginate gel was cross-linked with $CaCl_2$ solution. After that, all samples were washed three times with purified water and freeze-dried.

Results and Discussion

In this study, we have successfully fabricated DEX loaded microparticle coated 3D PLA scaffolds for bone regeneration. The particle size of DEX loaded microparticles was measured between 98-204 µm with uniform distribution.

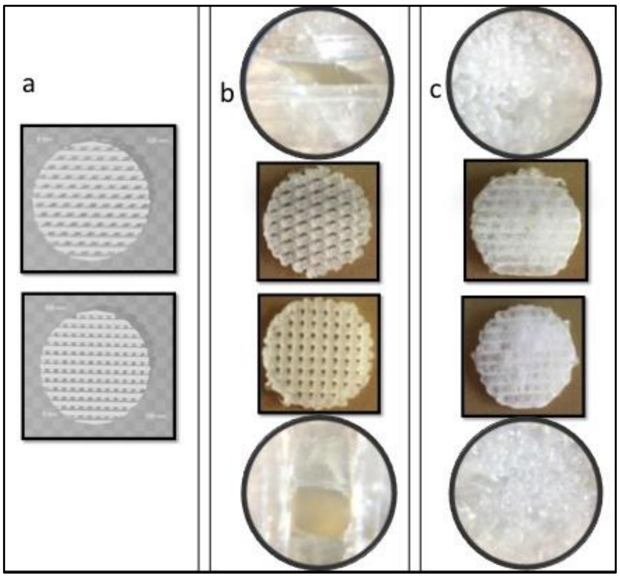

Figure 1. a) Schematic scaffold design, b) Fabricated scaffolds, and microscopic structure c) Coated scaffolds and microscopic structure

. Our results demonstrated that higher molecular weight of the PCL caused increased particle sizes. Besides, drug encapsulation efficiency were measured between 12-25%, and we have shown that microparticles which were prepared by using lower molecular weight PCL had the highest drug loading efficiency. The fabrication of 3D scaffolds was completed with success over the pre-designed model. As a result, we have indicated that results are reproducible and all samples contain the same amount of DEX loaded microparticles. Also, the coating enhanced the porosity and surface hydrophilicity, which will improve the cell attachment to the scaffold. Our 3D approach provides local DEX delivery on bone defects and may help bone regeneration.

Conclusion

In vitro results indicated that DEX loaded PCL microparticle coated PLA scaffolds can be proposed as a promising local controlled delivery system and regeneration support for the treatment of bone defects.

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PP-2. BIOMIMETIC APATITE COATING ONTO 3D PRINTED SCAFFOLDS FOR BONE TISSUE ENGINEERING APPLICATIONS

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Introduction

Bones are subjected to a wide variety of mechanical demands during activities of daily living and thus these tissues are often damaged. Although bone tissue possesses the self-healing ability, it is not able to heal from the large damage caused by a serious trauma or pathological lesions. In such cases, it necessary to use an external advanced treatments, such as tissue engineering which is a new approach to recreate complexity, stability and biologic function of bone tissue. Among the other important properties, osteoconductivity is essential for a bone tissue engineering scaffold to enhance the attachment and migration of osteoblasts and osteoprogenitor cells [1]. Biomimetic coating using simulated body fluid (SBF) is a simple alternative method to the harsh apatite coating processes [2].

In this study, we aimed to obtain bone-like apatite layer onto 3D printed tissue engineering scaffolds, by means of using a biomimetic approach.

Methods

The scaffolds with two different patterns were fabricated from filaments of poly(L-lactide) and polycaprolactone blend (PLLA/PCL, 70/30 w/w) using a 3D printer (Ultimaker 2-Go, Ultimaker, Netherlands). For all prints, a flow rate of 133%, a printing speed of 50mm/s, nozzle temperature of 173°C, plate temperature of 50°C were used. Inıtially, the geometry of the scaffolds were modeled using computer aided design (CAD) software (SolidWorks, Dassault Systèmes S.A.) and then converted to a G-Code file for printing. Prior to biomimetic coating, the surface of the scaffolds were modified by dipping them into 1M NaOH, saturated $CaCl_2$ and saturated K_2HPO_4 solutions, consecutively. After drying at 37°C, the 3D constructs were placed into falcon tubes containing 1x and 1.5X SBF solutions and incubated at 37°C for 8, 10, 14 and 18 days. The scaffolds were then removed from the solutions, rinsed with distilled water, dried and analyzed by different methods, including scanning electron microscopy (SEM), Fourier Transform Infrared spectroscopy (FTIR-ATR), Electron Dispersive Spectroscopy (EDS).

Results and Discussion

It was possible to produce scaffolds with square interconnected pores and thicknesses of 5.60mm. The single lay-down pattern of 0/90° and FD values of 600-800 µm were chosen for the scaffold design.

Figure 1 shows SEM micrographs of Ca-P coatings grown on the surface of 3D printed PLLA/PCL scaffolds after immersion into SBF. After 8 days, it was possible to obtain CA-P layer on the scaffolds incubated in both 1X- and 1.5X SBF solutions, without compromising the interconnectivity of the scaffolds. However, the morphological differences on the coatings were observed at higher magnification. The needle-shaped crystals intricately intertwined to form typical cauliflower HAp structures on the surface of scaffolds immersed into 1XSBF whereas a continuous layer of cauliflower (or hemispherical) structures was already formed on the scaffolds immersed into 1.5XSBF for 10 days. Moreover, EDS spectra of the coated samples confirmed the formation of apatite layer by showing the Ca and P elements. In FTIR analysis, a sharp band that corresponds characteristic P–O stretching appeared at 1030 cm^{-1} after Ca–P coating of the scaffold surfaces.

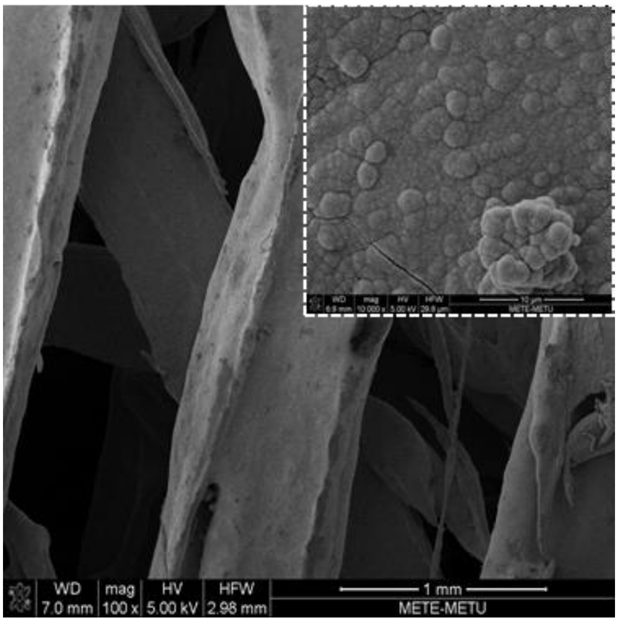

Figure 1. SEM micrographs of the developed coated scaffolds, exhibiting a fine and homogenous Ca–P layer onto 3D printed scaffold surface.

Conclusion

A simple biomimetic approach was described for the preparation of bone-like apatite coated 3D printed PLLA/PCL scaffolds. A homogenous Ca–P coating was produced on the surface by immersing in SBF solution with different concentrations. Bone-like apatite formation was observed on the surfaces of the constructs even after 8 days of immersion in 1XSBF.

The results suggest that the 3D printed scaffolds with bioactive coatings can be a promising candidate in bone regeneration.

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PP-3. THREE DIMENTIONAL RELATIONSHIP OF SUPRASCAPULAR NOTCH: A RADIOANATOMICAL STUDY

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Introduction

The anatomy of the suprascapular notch is an essential knowledge in entrapment of the suprascapular nerve. The aim of this study is to investigate the correlation between the suprascapular notch and anatomical landmarks adjacent to it.

Methods

A total of 121 scapulae were investigated and divided into three groups (U-shape, J- shape and V- shape) according to the classification of Iqbal who examined the scapulae for shapes of suprascapular notches. Using digital caliper the maximal depth, superior transverse diameter and middle transverse diameter of the suprascapular notch were measured. Furthermore, the distance between suprascapular notch and supraglenoid tubercle (a), the distance between suprascapular notch and medial wall of spinoglenoid notch (b), the distance between supraglenoid tubercle and medial wall of spinoglenoid notch (c), the distance between suprascapular notch and posterior rim of glenoid cavity (d) and the distance between posterior rim of glenoid cavity and medial wall of spinoglenoid notch (e) were also measured. The average and standard deviation (SD) of measurements were calculated in each shape. The correlation between each other was analysed.

Additionally, all parametres were measured in 124 patients' CT-images using Osirix MD software. The age and sex of patients were recorded. All measurements on CT-images were compared in compliance with age and sex.

Results and Discussion

It was found a significant correlation between the distance suprascapular notch and supraglenoid tubercle (a) and other distances (b, c, d, and e) separately.

Conclusion

Suprascapular nerve courses and is entraped in the distinct anatomical landmarks such as the suprascapular notch, spinoglenoid notch, spinoglenoid ligament. For operations associated with shoulder pathologies especially the entrapment of the suprascapular nerve, the detailed anatomy of the suprascapular notch is very important. The mean, SD and corralation of the measurments in each shape of suprascapular notch may help to model this area before operation practically.

PP-4. COMPUTER AIDED 3D VISUALIZATION OF RECTAL ANATOMY IN MEDICAL EDUCATION

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Introduction

The anatomy of rectum and related structures can be a complicated subject for medical students. In particular, it is difficult to comprehend the neighborhood of the rectum with variable volume structures such as bladder. Therefore, examination of rectum and related structures according to three-dimensional (3D) and interactive models can create a significant educational difference.

Methods

3D anatomical models of rectal region and associated structures were obtained through tomography images of an adult, healthy male. Sacrum, bladder, prostate, rectum and related bony structures were modeled by manual segmentation from the sections. All models and segmentations were done with Materialise™ Mimics Innovation Suite™ software. The lectures aided with interactive visual materials obtained from the sections and the conventional anatomy lectures with presentations were compared. A sample size of 52 achieves %95 power to detect an effect size(W) 0f 0.30 using Chi-Square Test with a significance level(alpha) of 0.05. For this study, 52 1st, 2nd, 3rd grade students from Ankara University School of Medicine were randomly selected. Participants were randomly divided into two groups. While the study group received courses supported by 3D models, the control group received standard anatomy lessons. Two different exams were conducted before and after the lessons and the results were compared between the groups.

Results

While there was no significant difference between the groups in the pre-course evaluation, the results of the study group were found to be better in the post-course exam.

Discussion

Three-dimensional and interactive models are becoming increasingly important due to difficulties in the provision of cadavers for medical education. Therefore it might be said that 3D visualizations and printed models will be used more extensively in higher education. 3D interactive models can be a useful tool as seen in this study. However, number of participants was limited in this study. Further studies are needed to get more exact results.

Conclusion

Computer aided and interactive 3D models of rectum and related structures can create a significant educational difference.

PP-5. DESIGN OF SPESIFIC BONE PLATES FOR CALVES

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Introduction

Computed tomography (CT) technique was born as a result of the combination of conventional X-ray imaging with computer[1]. Using CT -with appropriate software- it is possible to create three-dimensional digital models of the bones scanned[1]. Some software are available to enable implant design on these bone models[2]. Designing case-specific implants with the help of software is a practice that is done today[3]. 3D design is the creation of an object in three dimensions on the computer screen with the help of software. 3D modeling is the digitization of an object with all its surfaces / dimensions in 3D. Long bone fractures of the calf limbs are considered to be somewhat problematic, particularly in the presence of the appropriate implant[4]. The diameter of the calf bones is quite different from that of human and cat-dog bones[4]. The implants used for osteosynthesis in these animals are usually obtained from human or small animal orthopedics and modified. However, the use of specially designed implants for bone and fracture formation is ideal in orthopedics. In this study, it was aimed to construct 3D models by scanning the long bones with CT in calves and to design the specific osteosynthesis plaques in 3D.

Methods

Volumetric scan (CT scan) is performed with Siemens Somatom definition flash 256 dedector (435mAs, 120kVa, 0.75 mm section thickness) and the dimensions of the bone such as the length, breadth, thickness of the calve bones are obtained. The 3D scanning was performed in order to obtain the exact curvature of the bone. Plaque designs were made by using Materialise™ 'Materialise Mimics inPrint' and 'Materialise SurgiCase' software.

Results and Discussion

At the end of the study, 3D modeling of calf extremities long bones and plaque design for the humerus bone were performed.

Conclusion

It has been found that these specific plaques should differ from the standard plaques in form and size.

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PP-6. PRACTICAL AND RELIABLE METHOD IN VECTOR PLANNING OF INTERNAL MAXILLARY DISTRACTION OSTEOGENESIS: COMPUTER-AIDED 3D SURGERY

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Introduction
Computer aided simulation of maxillary distraction is very important tool at craniofacial that is complex anatomical region. As well as this item is useful in preoperative assesment of screw and plate placement, osteotomy line, it’s gives valuable information for predicting postoperative results.[1,2,3] The determination of the vector in internal distractors is very important as it cannot be changed later.[4,5] In this case report, we aimed to present a case that its definitive vectors had calculated with computer-aided program.

Case report
The maxillary advancement decision was taken on Seventeen year old male patient with bilateral cleft lip and palate. Preoperative DICOM (Digital Imaging and Communications in Medicine) data was recompose with Materialise Mimics® software. Internal distractor was placed in this software with virtual surgery. Distractor was placed to maxilla through virtual surgery and the final screw locations, osteotomy lines the accuracy of vectors direction was determined. Same time 3D model was obtained from printer. Surgery simulation was done on 3D model. Distractors were bending in according to virtual plan and maxilla was advanced 13mm.

Results
There were no complications in the postoperative period. Distractors followed preoperative planned vectors.

Discussion
The most frequent complications that requiring revision are maxilla's return to the sagittal plane in cleft patient because of palate scar.[6] Distraction osteogensis relapse rates are lower than in orthognathic surgery. But this advancement involves surgical difficulties.[7,8] With virtual planning and model surgery, the most suitable placement of plaque and screw can be easily determined during fixation. For all that the small problems that will be experienced in the direction of vector interrupt whole distraction process.

Conclusion
Especially in patients with cleft lip palate dentofacial anomaly, it is vital to determine the distraction osteogenesis vector precisely. Modeling of the intricate structure of bone anatomy and its virtual observability provides many advantages in surgery.

Figure

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PP-7. DECELLULARIZED MATRIX ENHANCED BIOINK FOR 3D BIOPRINTING

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Introduction

3D bioprinting provide an exciting expectation to create tissue-like structures in tissue engineering applications. However, most of the biomaterials used so far for bioprinting have been forced to represent the complex structure of the natural extracellular matrix which they fail. Therefore, the composing hydrogels are far from reconstructing natural cell environment and function.

In this study, we developed a bioink composition reinforced with decellularized matrix derived from animal tissues.
Which can provide microenvironment in 3D restructured, tissue growth and cell morphology. We provide a cell scaffolds using a biomaterials and decellularization extracellular matrix structure that is specific to tissues, especially cartilage and bone tissues. We examine the high viability and functionality of the decellularized matrix structures on the cells, which can be printed using the Bioprinting method.

Methods

Whole tissue samples were taken from fresh sacrificed lambs at the slaughterhouses were used for the study. After washing tissues with distilled water, samples were we first exposed the repeating 3 hours cycles of Triton-X-100 – PBS – SDS – PBS for 2 days on an orbital shaker. Samples were then homogenized and dried for two days using lyophilizator. Samples were then powdered and sterilized under UV light. Bioinks were prepared by mixing 3% alginate, and 1% gelatine with culture media (DMEM/F12 with 10% FBS, 1% PS). Collagen solution (Sigma) were added to the bioinks with a 1:4 ratio. Bioinks were used alone or mixed with decellularized extracellular matrix (dECM) tissues. Wharton jelly derived mesenchymal stem cells (MSC) at passage 5 or 6, cultured with DMEM/F12 with 10% FBS, 1% PS were used for the study. Study groups were set as 2D control cells, bioink with MSCs and bioink plus dECM group with or without MSCs. Bioinks were printed using Axolotl 3D Bioprinter. Printed samples were crosslinked with $CaCl_2$. Cells were incubated with culture media for 7 days and stained gel for cell viability, with DAPI/PI.

Results and Discussion

During light microscopic evaluation, cells were found in every layer of the gel. After 7 days, some disintegration at the gel were observed, indicating biodegradation. Some cells were hanging within the gel or sunk to the bottom as single or clustered groups.

However, most cells were found to be attached dECM flakes (Fig 1), showing high cell attraction and biocompatibility.

Conclusion

We believe that addition of decellularized tissue samples to the bioinks increase cell attachment, viability while creating a more natural cellular environment

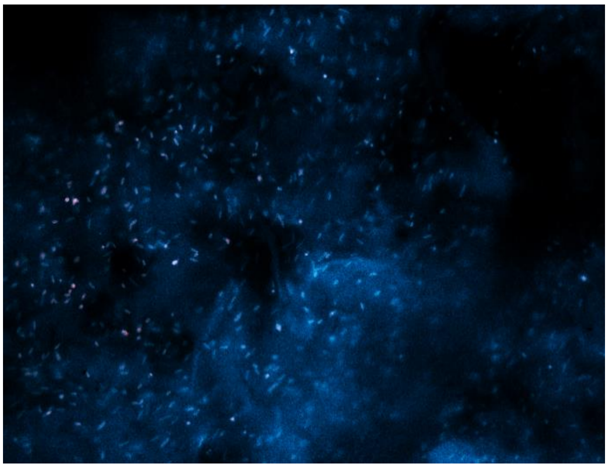

Fig 1: Alive cells in the Bioink plus dECM group can be seen stained with DAPI (blue dots) while dead cells were also stained with PI (red dots).

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Acknowledgements

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PP-8. CONTRIBUTION OF THE APPLICATIONS 3 DIMENSIONAL PRINTING IN MEDICAL EDUCATION

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Introduction

Changes in medical imaging technology have led to radical changes in medical practice. High-resolution imaging is contribute to not only medical practice 3 dimensional (3D) printing reconstruction possibilities, advanced MRI methods but also medical education. Especially in complex anatomical structures, changes in medical imaging technology provide new educational opportunities at all levels. On the one hand contribution to classical anatomy education models on the other hand due to the increased use of medical imaging the need for new education such as cross-sectional anatomy was born.

Methods

This poster is compiled with historical process and educational interdisciplinary point of the view of a broad spectrum of medical imaging methods and 3D applications that are always reflected in the medical education from undergraduate level.

Results Discussion and Conclusion

In Akdeniz University faculty of medicine, examples are given of related to special study modules applied in term 2 students. Potential application areas are discussed. New recommendations have been developed.

PP-9. BIODEGRADABLE POLYURETHANE ELASTOMERS FUNCTIONALIZED WITH Β-GLYCEROPHOSPHATE

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Introduction

During the last decade, development of 3D printed bone tissue engineering scaffolds has gained importance for the support and treatment of irregular bone damages[1]. Synthetic polyesters (PLA, PLGA, PCL etc.) were widely used in 3D printing process due to their commercial availability and safe biodegradation products. However, these polymers have limitations of functionality, elastic properties and biodegradation periods. There is still need for the development safe and functional 3D printable polymers with tailorable physicochemical and biodegradable properties. Polyurethanes (PU's) have proper biocompatibility, chemical diversity and adjustable viscoelastic properties and they can be improved as 3D printable materials[2]. In this study, segmental PU's with functional, elastomeric and biodegradable properties were aimed to develop by step-wise condensation polymerization. The functionality of PUs was enriched with osteogenic compound β-glycerophosphate (βGP). βGP is an intracellular signalling molecule for osteogenic gene expression and simulates the bone matrix surface and biomineralization with its phosphate groups.

Methods

In the first step of condensation polymerization, PU-βglycerophosphate (PU-βGP) viscous prepolymer was synthesized by reaction of polycaprolactone diol, 1-6-hexamethylene diisocyanate and functional diol group containing βGP. Polymerization conditions were optimized in terms of monomer mole ratio, reaction time and reaction temperature. The molecular weights of prepolymers were analysed by GPC. During the second step of polycondensation, segmental reactions were carried out in order to achieve elastomeric properties in PU-βGP macromolecular structure. The chemical structure of synthesized PU-βGP is given in Figure 1. The chemical and thermal properties of PU-βGP were examined by FTIR, DSC and TGA, respectively. Dynamic mechanical analyses were carried out with different tensile oscillation frequencies (1 Hz and 10 Hz) at temperature range of -125 °C and 175 °C in order to determine the viscoelastic properties of PU-βGP. Biodegradation studies were performed in hydrolytic, enzymatic and oxidative media during 75 days period.

Results and Discussion

The viscous prepolymer with molar ratio of 1.98:1.00 (HDI: PCL-diol) had number av. molecular weight 64650 according to GPC analysis. This result indicates that prepolymer reacted to critical molecular weight and can be 3D printable via precipitating in water.
FTIR results showed that β-glycerophosphate was integrated into PU macromolecular structure by creating urethane bonds. PU-βGP had superior viscoelastic properties during dynamic mechanical analyses. Tg transitions were recorded as -83.43 °C, -79.67 °C at 1 Hz and 10 Hz oscillation frequencies, respectively. Thermal degradation was observed in three steps due to segmental degradation of βGP, hard segment and soft segment.

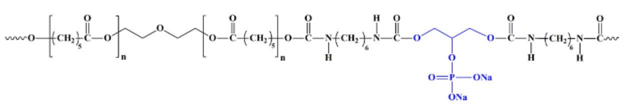

Figure 1. Chemical structure of β-glycerophosphate functionalized polyurethane.

PU-βGF biodegraded by surface erosion type morphology and 52 % weight loss was recorded at 21 days period in lipase media. Biodegradation reaction of polyurethanes is given in Figure 2.

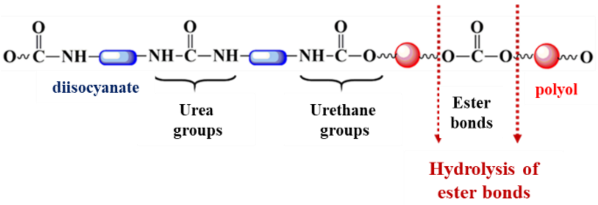

Figure 2. Biodegradation reaction of polyurethanes.

Conclusion

β-glycerophosphate chain regulated PU prepolymers showed promising properties for 3D printing process. Their segmental elastomeric nature, biodegradation behaviour and functionality arising βGP increases applicability in bone tissue engineering studies.

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Acknowledgements

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PP-10. MICROWAVE ASSISTED METHACRYLATED KAPPA CARRAGEENAN (KCA) BIO-INK FOR TISSUE ENGINEERING APPLICATIONS

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Introduction

3D bioprinting is defined to produce of biomaterials, living cells and biosignal molecules in layer form, desired shape, quantity and function. Materials or material-cell mixtures which have suitable viscoelastic properties and printable on a 3D printer is called bio-ink. *Kappa* carrageenan (κCA) is a natural polysaccharide including 3,6-anhydro-D-galactose and β-D-galactose-4-sulfate groups. The κCA resembles native glycosaminoglycans (GAGs) such as chondroitin-4-sulphate and dermatan sulphate, which are major components of native extracellular matrices (ECM). Because of that, κ-CA is a good candidate as a biomaterial for cartilage tissue engineering applications.
The chemical functionalization of the κCA backbone with a methacrylate group (MA) ensure enhanced structural stability under physiological conditions. The MA-κCA can be crosslinked with UV light in the presence of a photo-initiator after its chemical modification. Therefore, more stable κCA hydrogel structures in the body temperature are produced.
MA-κCA synthesis remains suboptimal and needs to be improved, especially in terms of optimization and efficacy. Microwave energy provides selectivity, effectiveness, and speed, which allow saving of energy and time relative to conventional heating. Also, in the literature, methacrylated *kappa* has been subjected to both physical and chemical reactions for hydrogel formation [1]. Within the scope of the study, it was aimed to increase the efficiency of methacrylation reaction i.e. to increase degree of methacrylation, shorten the reaction time and reduce methacrylic anhydride usage by microwave energy. As the degree of methacrylation increases, hydrogels with high mechanical strength and viscoelastic properties are expected to be obtained.

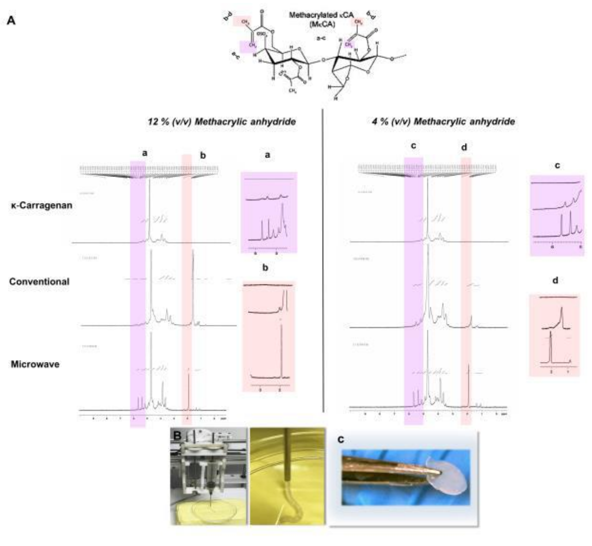
Methods

Methacrylated κCA (MA-κCA) was synthesized by microwave (Mw) assisted methacrylation reaction in comparison with conventional method [1]. In this method, 1000W Mw energy was applied for 5 minutes. Methacrylic anhydride has been tested at different ratios (12% and 4%). MA-κCA was characterized by 1H NMR spectroscopy. “Fab@home” (extrusion-deposition based system) 3D bioprinter was used for the printing of MA-κCA. Bioprinted MA-κCA hydrogel was crosslinked under UV (365 nm, 200mW/cm2) in the presence of photoinitiator (Irgacure®2959).

Results

κCA and methacrylic anhydride were successfully integrated via microwave-assisted methacrylation. ^{1}H NMR spectroscopy of MA-κCA were given in Figure 1-A and methacrylation degree (DM) of *kappa* carrageenan was determined from this data. 1H-NMR results showed that Mw-MA-κCA with 4% MA had a much higher DM (85±5%) than that of MA-κCA (29±5%).
Hydrogel solution (bio-ink) was printed successfully (Figure 1-B) with a thickness of 1mm and a diameter of 6 mm in cylindrical (disc) shape (Figure-1C).

Figure 1. A: 1H-NMR spectra of MA-κCA, B: Printing process and printability of Mw-MA-κCA ink, C: Bioprinted and UV cross-linked Mw-MA-κCA hydrogel disk.



Conclusion

We report the preparation of highly methacrylated □CA with□□85% DM by Mw-assisted methacrylation. Compared with conventional methacrylation method [1], DM of κCA was significantly increased even with the use of low concentration of methacrylic anhydride by microwave induced methacrylation method. Also this is the first study, introducing a stable hydrogel formation by only chemically crosslinked Mw-MA-□CA. Mw-MA-κCA can be used as a bio-ink for tissue engineering applications.

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‡: These authors contributed equally to the work.

PP-10. 3D PRINTED BONE TISSUE SUPPORTS MODIFIED WITH ZEOLITE A

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Introduction

3D printing technology is an emergent field, which allows manufacturing personalized implants with accurate end-results. 3D printed implants have been widely used in the medical field especially in bone and dental tissue injuries1. Since metallic implants have been reported with the risk of infection, destruction of bone tissue and osteoporosis, the development of personalized polymeric implants with suitable mechanical and biocompatible properties become important. In this study, it is aimed to manufacture 3D printed polylactic acid (PLA) based bone tissue support materials, having modified surfaces with zeolites. Zeolite layer on the surface of PLA bone support materials expected to increase biocompatibility during the first stage of implantation.

Methods

3D-printed bone tissue support material was designed using Solidwork software. The diameter of the extrusion nozzle was 0.4 mm and the thickness of each layer was designed to be 0.1 mm. During the printing process, the PLA filament was drawn and melted at 205 °C followed by extrusion through the print tip to the base which was 40 °C.

Zeolite A particles were synthesized according to literature2 and characterized with SEM. The surfaces of the PLA bone tissue supports were coated with Zeolite A in the presence of natural polymer3 via spin coater in order to provide biocompatible monolayer coatings on PLA surfaces. Manufactured bone support materials were characterized in terms of chemical, thermal, morphological and mechanical properties. The surface chemistry, surface wettability and surface free energies of the zeolite-modified structures were investigated by XPS, ATR-FTIR, spectrometer and goniometer, respectively. Moreover, osteoblast cells-material interactions were planned as future works.

Results and Discussion

After 3D printer processing, ATR-FTIR and DSC-TGA analysis findings show that the PLA structure maintains its chemical and thermal properties. The DSC thermogram of 3D printed bone support material is shown in Figure 1. In addition to Tg and Tm transitions confirming PLA's thermal properties, thermal decay was started to observe above 350°C.

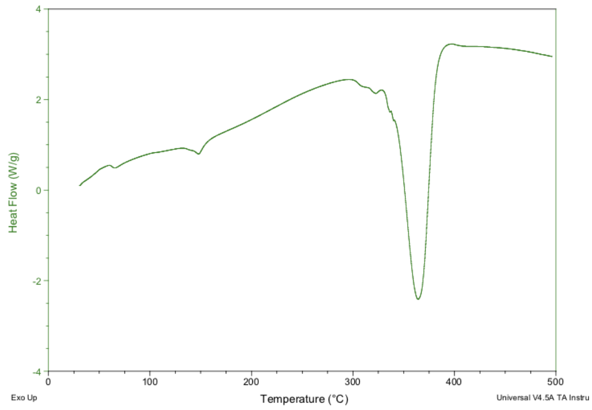

Figure 1. DSC thermogram of 3D printed PLA bone support material. Heating rate 10°C/min, N2 atm. Zeolite A particles were synthesized successfully and coated on PLA surface without showing any agglomeration.

Conclusion

PLA bone support materials were manufactured by 3D printing process without any thermo-chemical deformation. Surface of PLA supports were modified with Zeolite A via spin coating. The data obtained provides important outputs for the development of hard tissue support materials with tailored surface properties.

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Acknowledgements
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PP-11. IN SITU BACTERIAL CELLULOSE PRODUCTION SUITABLE FOR NEOVASCULARIZATION USING 3-D PRINTED POLYLACTIC ACID TEMPLATE

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Introduction
The skin, which is the largest organ of body has many important functions, including protection against external physical, chemical, and biologic assailants, as well as prevention of excess water loss from the body and a role in thermo-regulation [1]. Damage to the skin, such as burns, diabetic ulcers or injuries may sometimes be very serious and potentially life-threatening conditions. The skin, which is severely damaged due to the above-mentioned problems, may not spontaneously regenerate itself [2]. Researchers have been focusing on natural materials for skin regeneration due to significant constraints for autologous skin transplantation [3], the manufacturing and maintenance costs for synthetic/semi-synthetic skin substitutions, and the lack of support for neovascularization[4]. Bacterial cellulose (BC) is an ideal polymer for medical field because of its favorable properties, such as its biocompatibility, high purity, mechanical stability, high moisture content, 3-D coherent network of cellulose nanofiber structure, and suitability for the modifications both during and after the production [5]. Many studies have been carried out with BC for medical applications as artificial vein, ureter, urethra, bladder or myelin sheath because of its sheet structure[6], wound dressing, artificial skin, and scaffold for tissue engineering because of its high mechanical properties[7]. The aim of this study is to produce BC with an innate vascular network allowing for cell migration and neovascularization using polylactic acid (PLA) template printed by a 3-D printer.

Methods
BC membrane was biosynthesized by *Gluconacetobacter xylinus* (ATCC 700178 strain) using a static incubation method. Active culture of *G. xylinus* was inoculated at the concentration of 2% v/v to the modified Hestrin & Schramm (HS) medium. Vascular structured PLA templates (3 cm diameter of the template and 0.6-1 mm diameter of the channels) were printed by a 3-D printer and then placed into BC production media. At the end of incubation period (in static condition at 30°C for 5-7 days), BC membrane was harvested PLA template and cell debris was removed using chlorofom and 0.1 M NaOH solution.

Results and Discussion
As a result of the ATR-FTIR analysis, the correlation between pure BS and PLA was 0.233936, and the correlation between pure BC and BC produced using the 3-D printed PLA template was 0.983566. This shows that the chloroform and BC washing process successfully removes the PLA from the BC membrane. After the removal of the 3-D printed PLA template from BC membrane, it was observed that the channels with a diameter of 0.6-1 mm were formed (Fig.1). These channels will allow endothelial cells (cell lengths of 98-139 µm) to migrate and attach there for neovascularization.

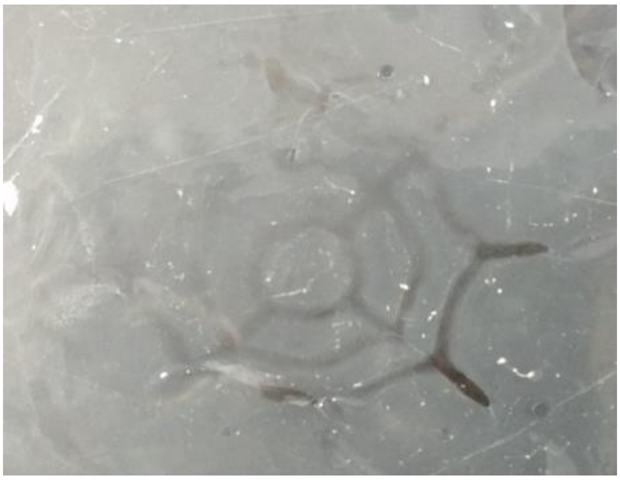

Figure 1. Macro image of the channels formed in the BC by the 3-D printed PLA templeted (0,6-1 mm in diamaeter of the channels).

Conclusion

The macro image (Fig.1.) shows that the obtained channels are large enough to allow the cells for migration and neovascularization. This has shown promising results in scientific research for artificial skin and wound dressing studies of bacterial cellulose, overcoming the disadvantage of existing skin substitutes that do not support neovascularization.

References

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