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Tissue engineering and scaffolds in dentistry

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Tissue engineering

Aims: Scaffold creation for remodelling of injured, or missing tissues; used by different cells, growth factors or any other materials what can promote this process.

Techniques: The combination of different organic, and inorganic, hydrophilic, and hydrophobic systems, used by various polymerization methodes.

Tools: Different tolerable polymers which could be degradable in appropiate conditions.

Strategies

used by biodegradable matrix or inorganic scaffold

- Conduction of the repair process,
  isolation from the environment

- Induction of the repair process,
  bioactive materials

- Purposeful induction of repair process ,
  not only bioactive materials, but the cells
  (stem cells) were added
  (guided e.g. to soft tissues, or bone tissues)

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Requirements to tissue (bone) scaffold materials

Biocompatibility:
The ability to work in an appropriate host , not triggered negative response .
Osseointegration:
Chemically connection can create between the material and tissue. (bioactivity)
Biodegradability:
The material can degradable/vanish, and new tissue can growth in this space .
Osseoconductivity:
The material can support the bone.
Osseoinduction:
The ability to induce differentiation of the cells to an osteoblastic phenotype .
Osseogenesis:
New bone creation in the present of greaft material.

ANZ J Surg 2001;71:354; J Mater Chem 2010;20:8747; J Mater Chem B 2013;1:1081.

Possibilities to replacement of extensive local bone

	Advantages	Disadvantages
Autograft	Standard	Limited availability the graft
Allograft	Same species, so similar structure, without osteoblasts	Postoperative infections, Risk of fracture, or any other infection/disease transmission
Xenograft	Easy availability, adequate source	Immunogenic properties/rejection/virus infection
Alloplastic graft	Availability, sterility	In the most of cases the lack of osteoinduction

ANZ J Surg 2001;71;354

Alloplastic grafts

Ideal synthetic bone graft substitutes

Good mechanical properties “load-bearing”

Long term degradability to prevent fatigue fractures

Promoting bone formation (“osteogenesis”).

Bohner M. et al. J Eur Ceram Soc 2012;32:2663

Tadic D, Epple M. Biomaterials 2004;25:987

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Solid graft materials

- Inorganic materials
  - Calcium-phosphate (β–TCP), hydroxyapatite, silicates, sulfates

- Organic components
  - Natural materials
    (collagene, fibrin fibers, etc.)
  - Polymers (synthetic or natural)
    (natural: glycolic-acid, lactic-acid, hyaluronic acid, etc.
    synthetic: poly-urethane, poly-methyl-methacrylic acid)

- Composites

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Polymers, as scaffolds

Different polymers and co-polymers for solid scaffold

- poly(DL-lactic acid) PLA
- poly(L-lactic acid) PLLA
- poly(lactic-co-glycolic) acid PLGA
- poly(propylene glycol fumarate) PPF
- poly(DL-lactic acid)-co-poly(ethylene glycol)-mono methoxy ether PEG-PLA
- PEG-PLA functionalized with Biotin

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Synthesis of scaffolds

- There are some possibilities
- One of the most frequented used is e.g.:
- Scaffold creation with solid lipid porogen materials

  and hot organic solvent extraction method
- Or electrospinning method

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Electrospinning

- Electrospinning is a technically easy methode
- Electric force driven nanofiber generating process
- Direct create extracellular matrix like structures
- Various polymer solution help to reach the biological activity
- Construction and structure work together for more effectiveness

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Critical points

- There are some critical points
- Slow acceleration
- Rapid acceleration
- Zone of solidification
- Taylor cone

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Possibilities for regulation

- Changing of fiber diameter possible in different ways
- Screen distance (growing fiber diameter is decreasing)
- Electric potential (growing fiber diameter is decreasing)
- Flow rate (with increasing the fiber diameter is increasing too)
- Concentration (with increasing the fiber diameter is increasing too)

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Polymers for electrospinning

Chemical formulas of polymers for electrospinning technique.

Different biomaterials can create from these.
Examples:

poly(lactide) PLA, poly(glicolic acid) PGA, poly(aminoacid alkyl ester) phosphasene, poly(caprolactone) PCL, poly(caprolactone-co-ethyl ethylene phosphate), polycarbonate, poly(ethyleneglycol) PEG, polyethyleneimin, polyurethane PU, poly(vinyl alcohol) PVA

Electrospinning products

Direct electrospinning methode for preparation of

<u>wound healing material</u> , guiding-electrode and

airblowing for the better controlled reaction.

Posteriorly UV-treated electropinning produced

PVA/AgNO3 net covered fiber

Electrospinning technque used for hemoglobin and

myoglobin crosslinked material preparation from

2,2,3-trifluoro-ethanol solution.

Cell attachments

Effects of the different scaffold structures

to the cell attachment possibilities

Micropore scaffolds

Microfiber scaffolds

Nanofiber scaffolds

Increasing the possibilities of cell attachments

Dent Mater. 2010 Apr;26(4):275-87.

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Surface modification

The effect of sufrace modification

From the machine-smooth to the micropits and the micropits

with nanonodules increasing the average roughness, the surface

area, and the possibilities to the cell attachments

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Dent Mater. 2010 Apr;26(4):275-87.

Biomimetics

The micro-nano-hybrid surface structure similar

to the mineralized bone matrix structure.

Ca-binding protein

like structures

Dent Mater. 2010 Apr;26(4):275-87.

Ostim (Heraeus Kulzer)

- Synthetic, nanocrystalline structure, homogen **hydroxiapatite**
- Waterbased, paste material
- Osteokonductive, accelerate the remodelling of bone
- Fully replaced by new bone meterial

Kamboj M, Arora R, Gupta H. Comparative evaluation of the efficacy of synthetic nanocrystalline hydroxyapatite bone graft (Ostim®) and synthetic microcrystalline hydroxyapatite bone graft (Osteogen®) in the treatment of human periodontal intrabony defects: A clinical and denta scan study.
J Indian Soc Periodontol. 2016;20(4):423-428

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Bio-Oss (Osteohealth)

- Natural origin (bovine) bone mineral content
- Osteoconduktive effect accelerate the bone formation
- Small sizes of crystals, so slowly fully built in to the bone

Bio-Oss Collagen®

- Bio-Oss Collagen® Bio-Oss® Spongiosa granules (0.25-1 mm)
- 10 percent purified porcine collagen
- This collagen can hold together the particles without membrane
- **Absorbed within 4-6 weeks**

Shankar T. Gokhale and C. D. Dwarakanath, The use of a natural osteoconductive porous bone mineral (Bio-Oss™) in infrabony periodontal defects, J Indian Soc Periodontol. 2012; 16(2): 247–252.

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VITOSS® (Stryker)

- Ultra-porous
- Resorbeable β-tricalcium phosphate for 3-D reconstruction
- VITOSS, VITOSS FOAM and VITOSS bioactive FOAM patented and so on
  - Indications

  For skeletal system (i.e., the extremities, pelvis and posterolateral spine(degenerative diseases, tumors, bone defects due to trauma)

https://www.stryker.com/us/en/spine/products/vitoss.html

NanOss™ (RTI Surgical)

- Nano-crystalline calcium-phosphate
- From precipitated calcium-phosphate nanoparticles under high pressure, and temperature a thick and transparent nano-crystalline structure created
- „the first material that duplicates the microstructure, composition and performance of human bone"
- highly osteoconductive and remodels over time into human bone
  - applications area
    in the sports medicine, trauma,
    spine and general orthopaedics markets

Am. J. Biochem. Biotechnol., 2: 41-48. 2006

https://www.rtix.com/en_us/products/product-implant/nanoss-advanced-bone-graft-substitute

OP-1®
(Stryker Co. USA)

- OP-1 Implant is an osteoinductive and osteoconductive bone graft material
- 3.3 mg of recombinant human BMP-7 (rhBMP-7) and 1 g of purified Type I bovine collagen

In 2001, the FDA approved OP-1 Implant for posterolateral lumbar spine fusion and for the treatment of
long bone nonunion fractures

Olympus Biotech from 31. May 2014. stopped the American distribution of OP-1® IMPLANT, OP-1® PUTTY, BioEZE™, and BioVERSE™ products

https://www.olympus-global.com/en/news/2010b/nr101207op1e.html

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