The advantages and use of ceramics in medicine

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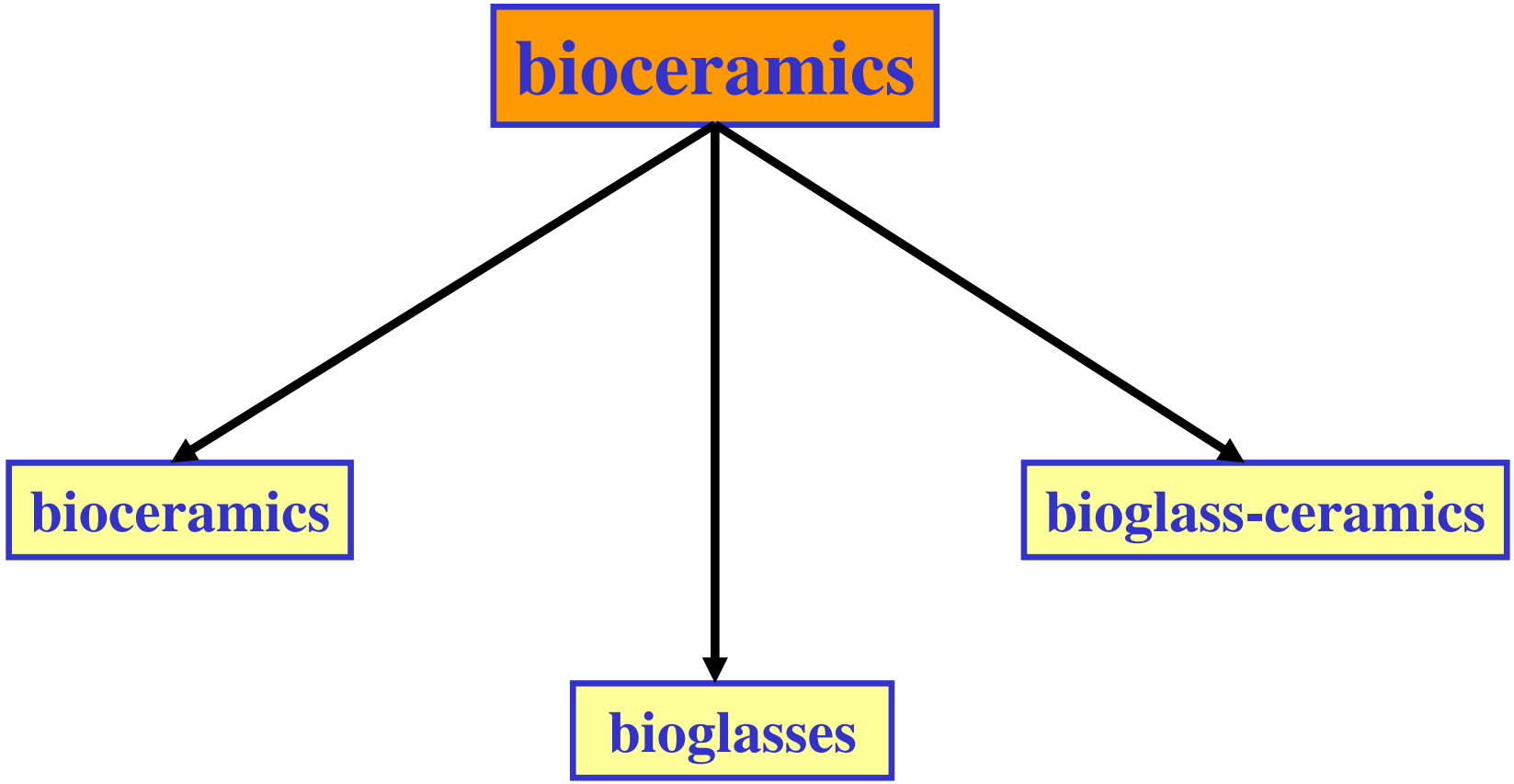
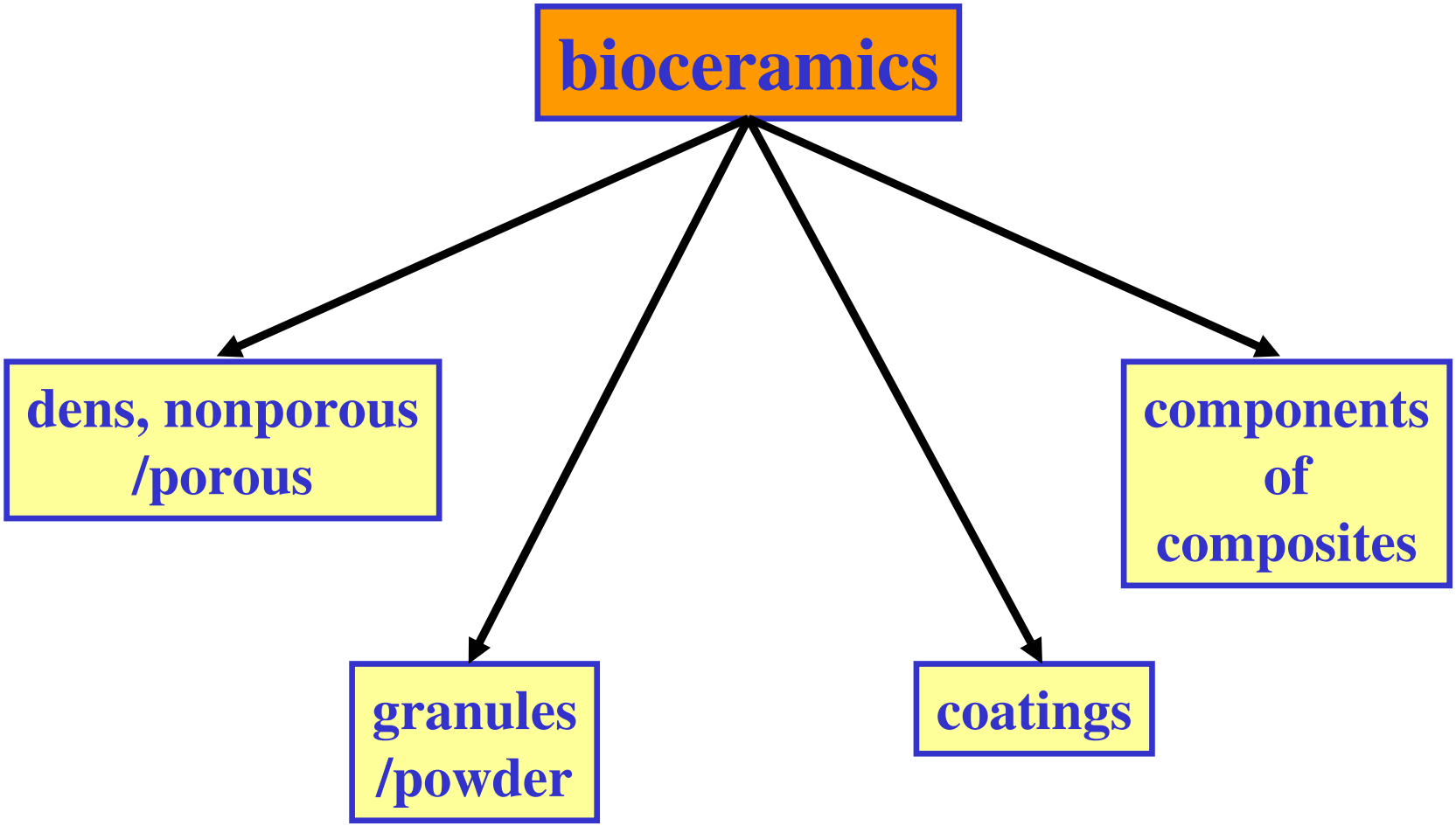
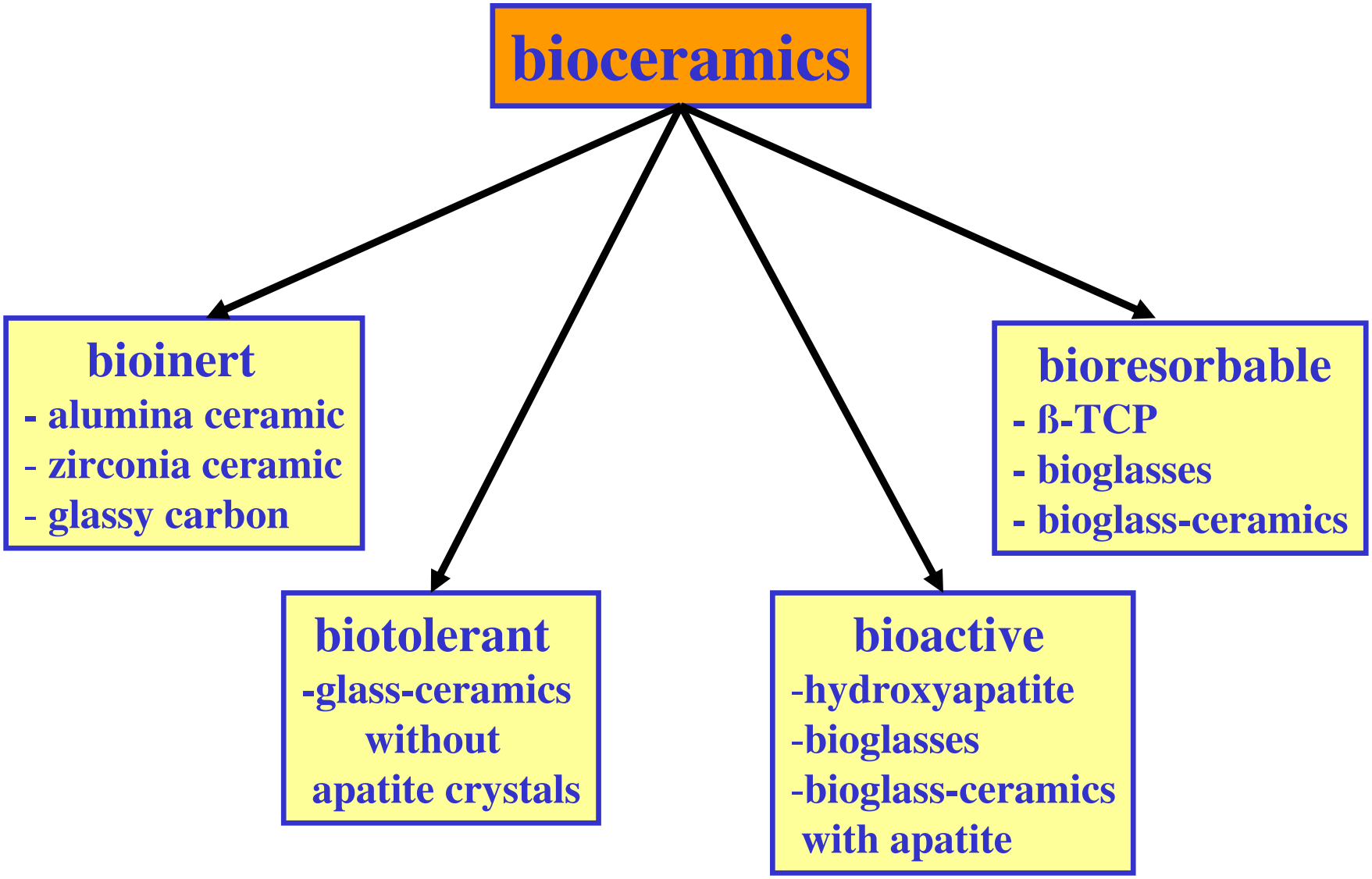
ORTHOSONIC CERAMIC CONFERENCE Saturday 6th July 2002


bioceramics
bioceramics
bioglasses
bioglass-ceramics


bioceramics
dens, nonporous /porous
granules /powder
coatings
components of composites


bioceramics
bioinert
- alumina ceramic
- zirconia ceramic
- glassy carbon
biotolerant
-glass-ceramics
without
apatite crystals
bioactive
-hydroxyapatite
-bioglasses
-bioglass-ceramics
with apatite
bioresorbable
- ß-TCP
- bioglasses
- bioglass-ceramics

alumina bioceramic
- high-density / high-purity -

⇒ good biocombatibility

⇒ excellent corrosion resistance

⇒ high wear resistance

⇒ low coefficient of friction

⇒ very low surface roughness values

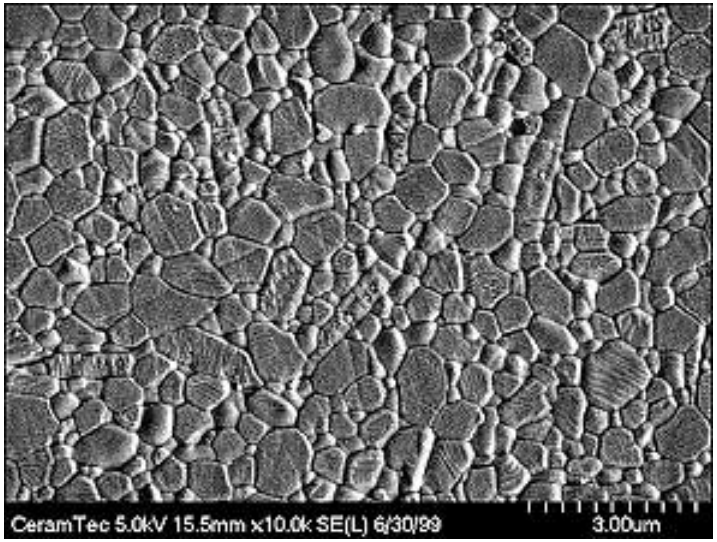
⇒ high strength

⇒ high fracture toughness

properties of alumina bioceramic

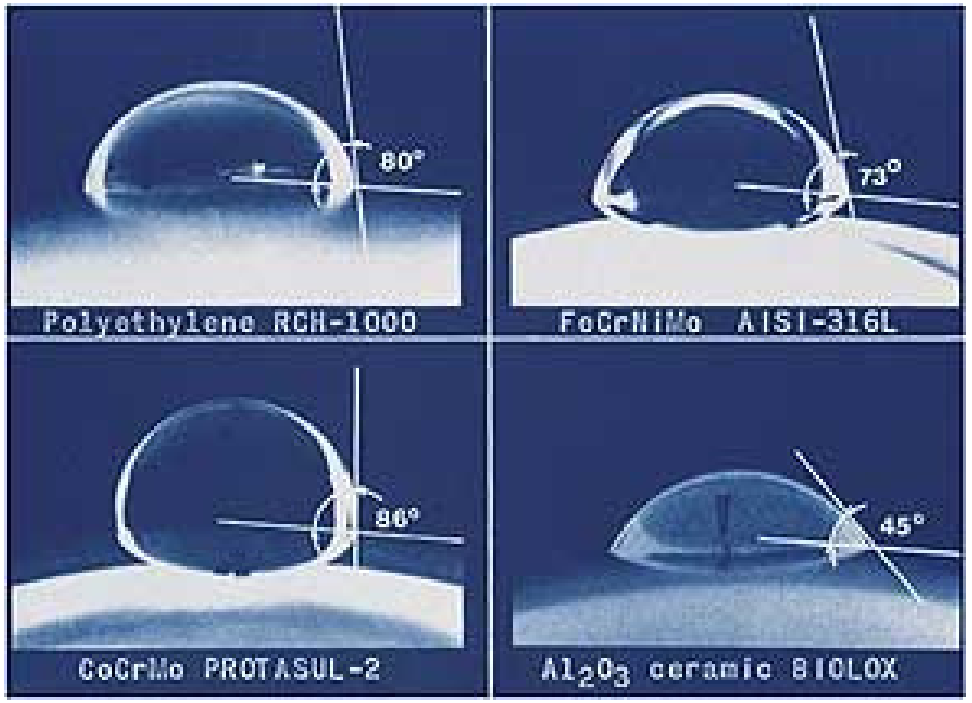
properties	alumina bioceramic	ISO alumina standard 6474
Al_2O_3 content [wt-%]	> 99,8	≥ 99,5
density [g/cm³]	> 3,93	≥ 3,9
average grain size [µm]	3-6	< 7
hardness [HV]	2300	> 2000
compressive strength [MPa]	4500	
bending strength [MPa]	550	400
Youngs Modulus [GPa]	380	
fracture toughness [MPa*$m^{-1/2}$]	5-6	

alumina bioceramic



microstructure

contact angle




alumina ceramic
hip prostheses balls & sockets
kerato-prostheses corneal replacements
knee prostheses
bone screws
dental implants
alveolar ridge
maxillofacial recon-structions
middle ear implants

clinical applications of alumina bioceramic

properties of zirconia bioceramic

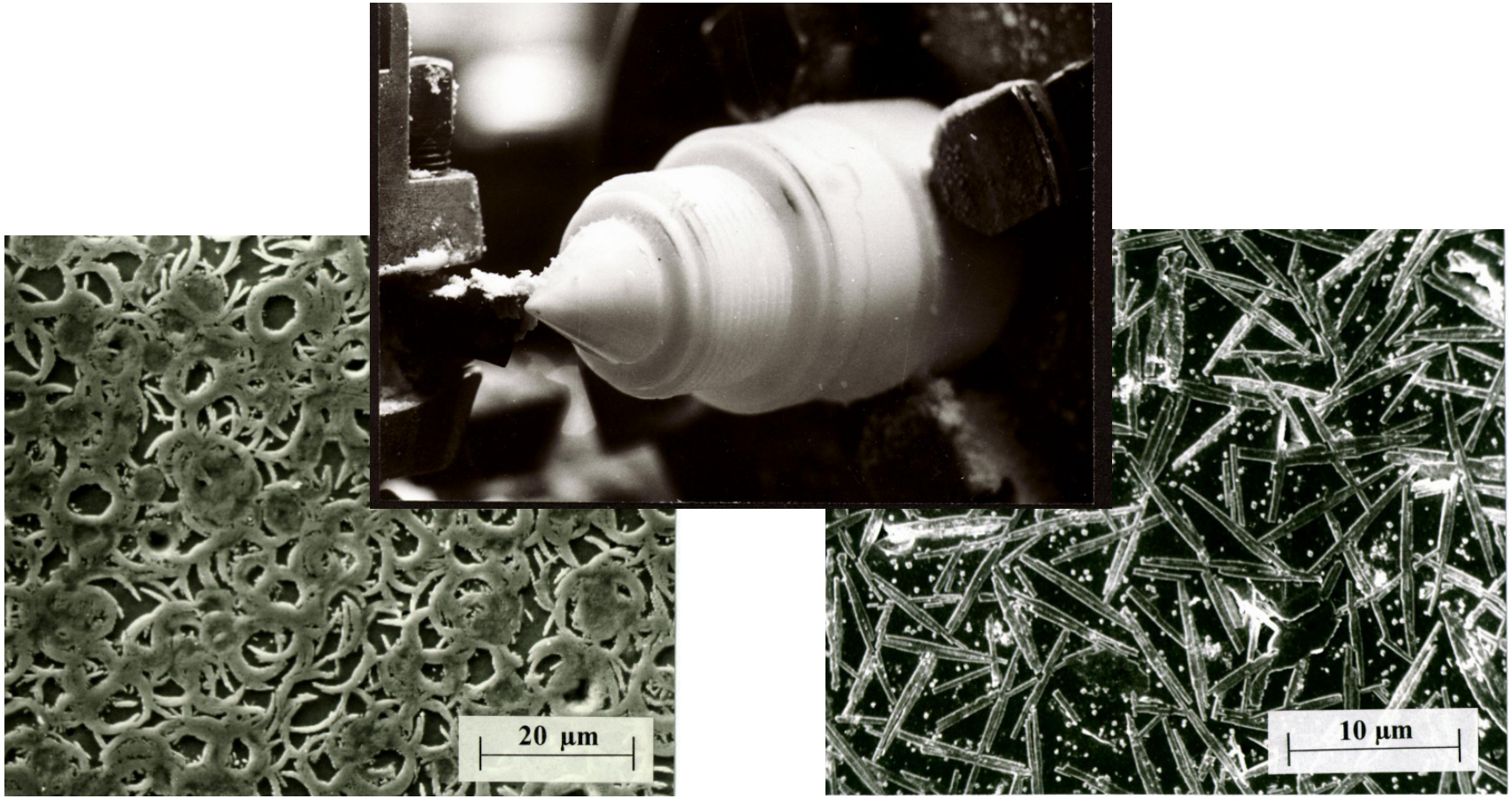
properties	zirconia bioceramic	alumina bioceramic
ZrO_2 / Al_2O_3 content [wt-%]	> 97	≥ 99,8
density [g/cm³]	5,6 – 6,1	≥ 3,93
average grain size [µm]	1	3-6
hardness [HV]	1300	2300
bending strength [MPa]	1200	550
Youngs Modulus [GPa]	200	380
fracture toughness [MPa*$m^{-1/2}$]	15	5 - 6

Moje zirconia implants

biotolerable bioglass-ceramics

♠ systems

⇒ mica glass-ceramics (machinable) - Bioverit® II



microstructure of mica glass-ceramics with plate like (right) and curved mica crystals (left, Bioverit®II), scanning electron micrograph

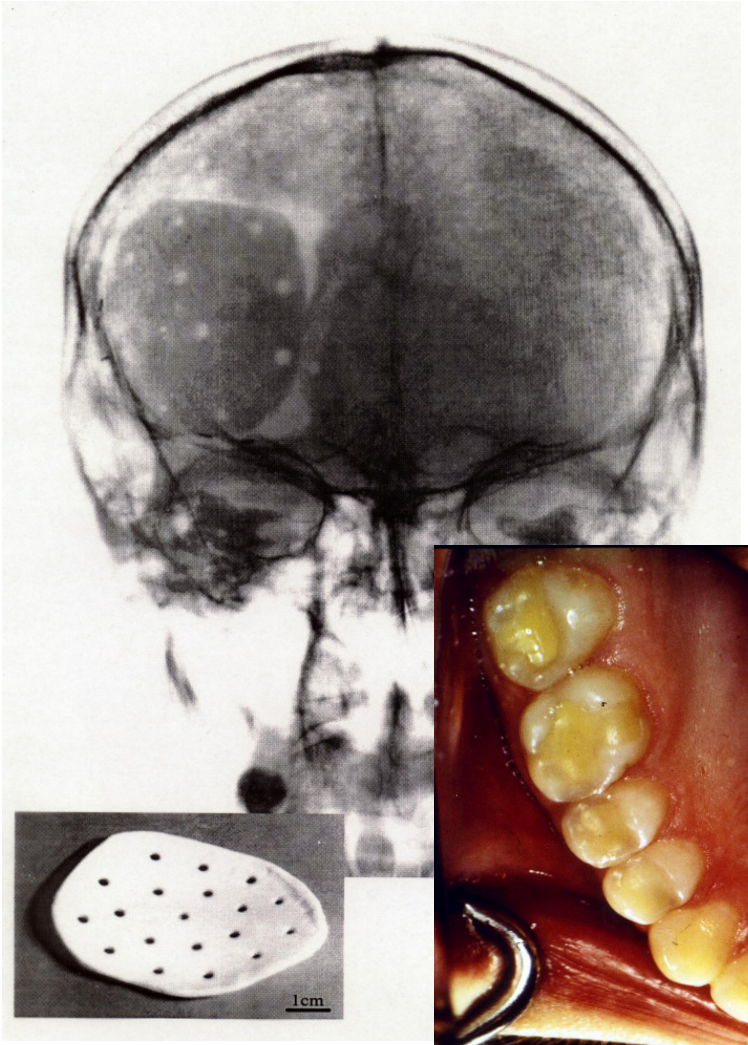
biotolerable bioglass-ceramics

♠ systems
- ⇒ mica glass-ceramics (machinable)
- ⇒ leucite glass-ceramics
- ⇒ lithium silicate glass-ceramics

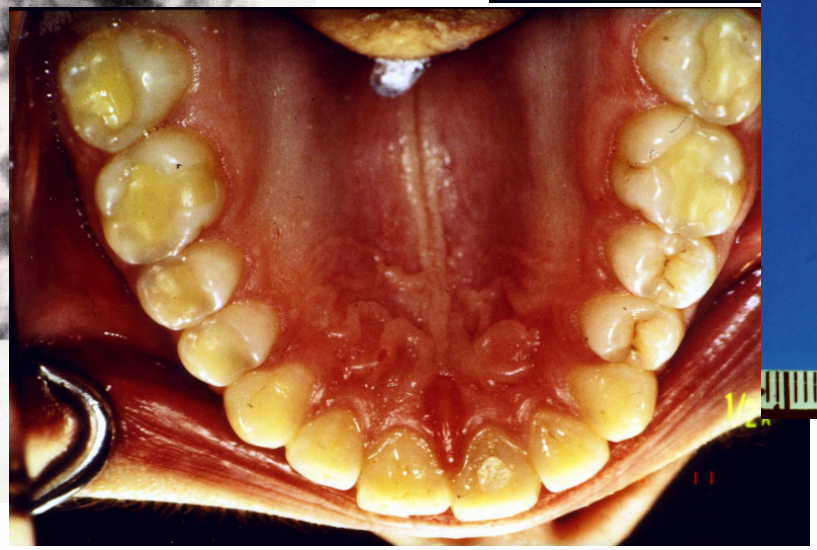
♠ properties
- ⇒ biocompatible, non-toxic
- ⇒ high chemical resistance
- ⇒ good mechanical properties

♠ clinical applications
- ⇒ dental restorations
- ⇒ middle ear implants
- ⇒ skull reconstructions

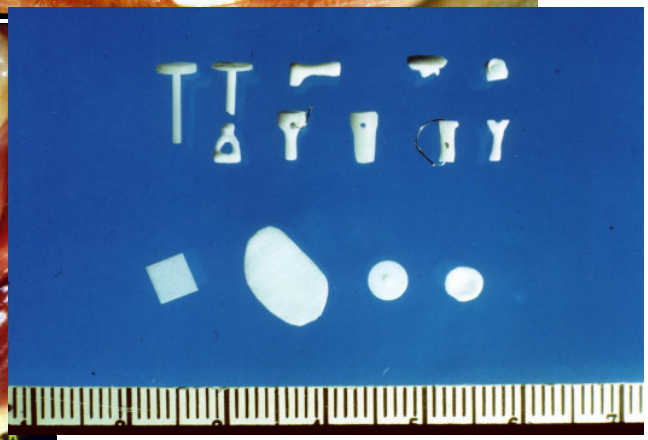
biotolerable mica bioglass-ceramic Bioverit® II



skull cap



dental restorations - inlays



middle ear implants

bioactive bioceramics

hydroxyapatite – $Ca_{10}(PO_4)_6(OH)_2$

♠ properties

⇒ high biocompatibility

⇒ high bone bonding ability

⇒ high chemical resistance

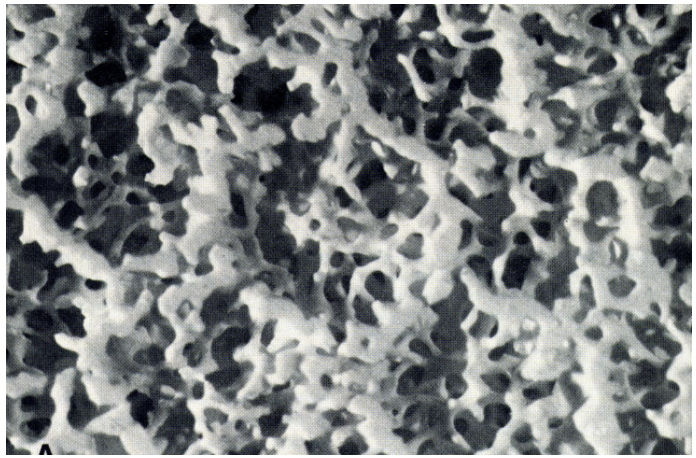
⇒ low mechanical strength

♠ clinical applications

⇒ bone void filler

(nonporous, porous – coraline)

⇒ coatings



microstructure of a porous hydroxyapatite ceramic

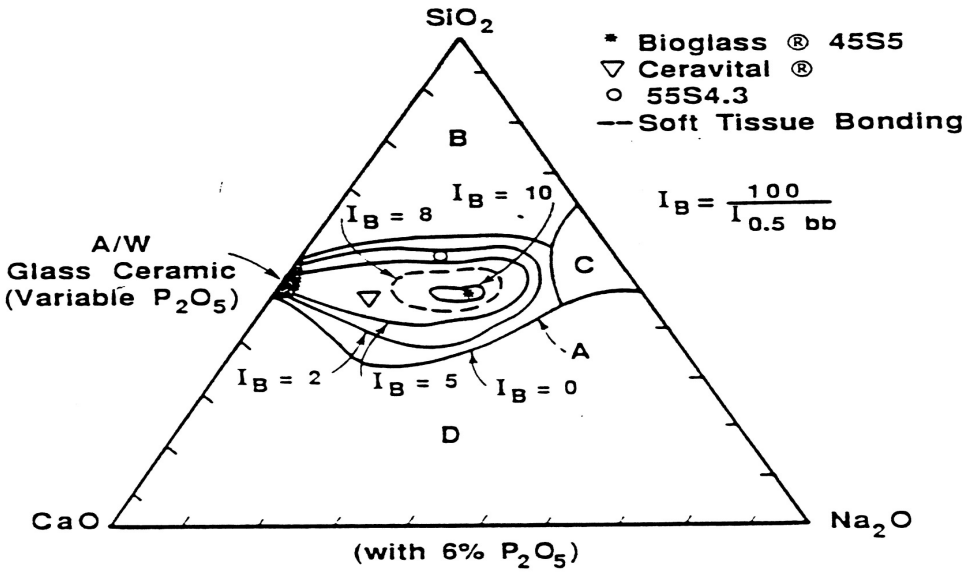
bioactive bioceramics

hydroxyapatite – $Ca_{10}(PO_4)_6(OH)_2$

bioactive bioceramics

bioglass®

♠ sytem: Na_2O-CaO-SiO_2-P_2O_5-(F^-)



A. Bone Bonding Boundary at 30 days or less
B. Non Bonding, Reactivity is too low
C. Non Bonding, Reactivity is too high
D. Non Bonding, Non Glass-Forming

bioactive bioceramics

bioglass®

♠ properties

- ⇒ excellent biocompatibility
- ⇒ high bio reactivity
- ⇒ high bone bonding ability
- ⇒ low chemical resistance
- ⇒ low mechanical strength

♠ clinical applications

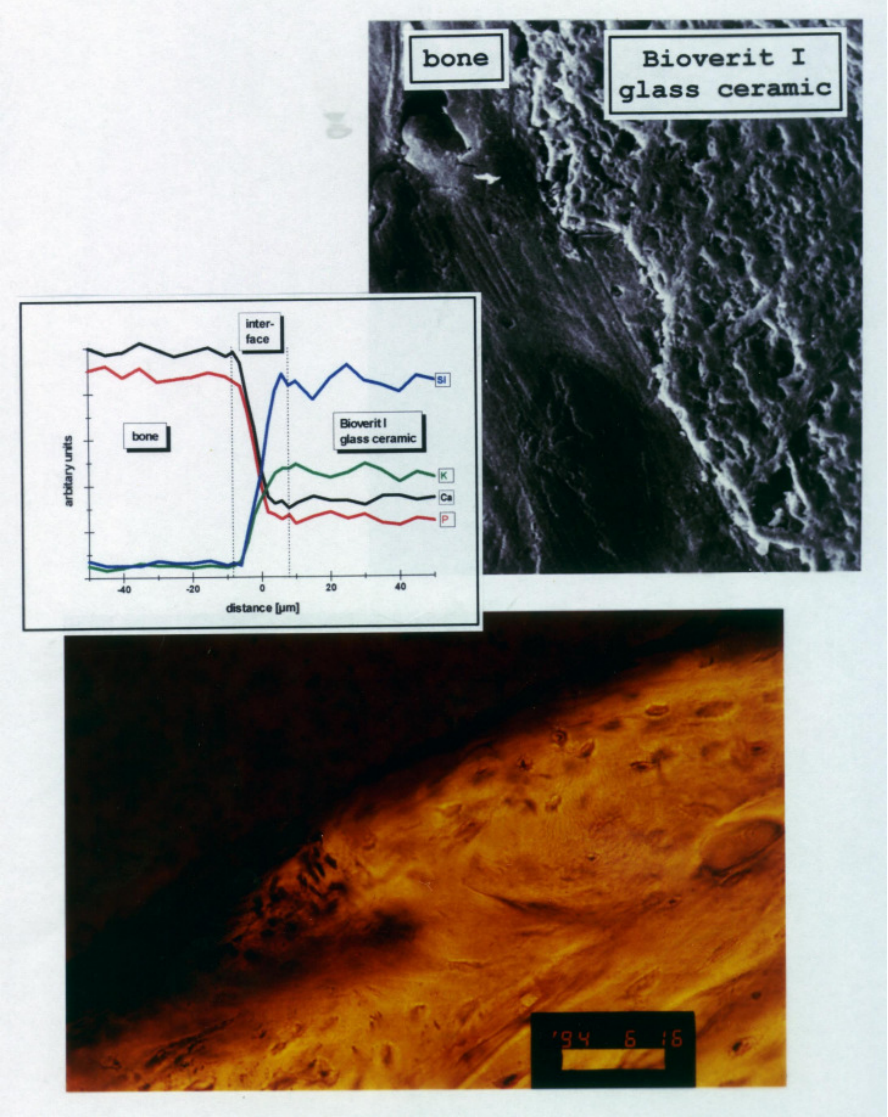
- ⇒ bone void filler
- ⇒ coatings
- ⇒ composites
- ⇒ middle ear implants
- ⇒ dental implants

bioactive bioceramics

bioglass-ceramics

bioglass-ceramics	Ceravital®	Cerabone®	Bioverit®
System	Na_2O-CaO-SiO_2-P_2O_5	MgO-CaO-SiO_2-P_2O_5-F^-	Na_2O-K_2O-MgO-Al_2O_3-CaO-SiO_2-P_2O_5-F^-
crystal phases	apatite	apatite, wollastonite	apatite mica
bone bonding ability	very high	very high	high
chemical resistance	low	high	high
mechanical strength	low	high	high

bioactive bioglass-ceramic Bioverit® I



electron-beam micro-probe investigation of the intergrowth zone between bone (left) and bioglass-ceramic Bioverit® I (right)

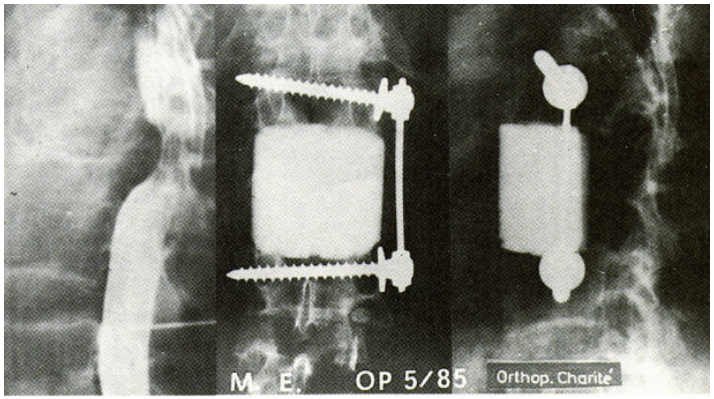
intergrowth between bone and glass-ceramic Bioverit® I (scanning electron micrograph)

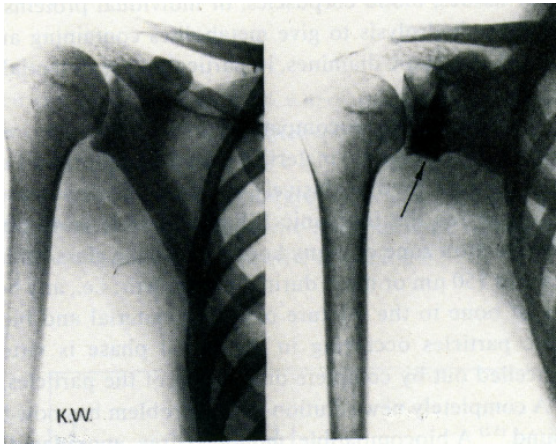
intergrowth between bone (yellow) and glass-ceramic Bioverit® I (optical micrograph)

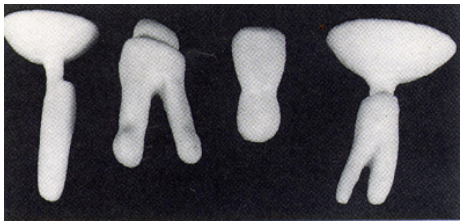
bioactive bioceramics

bioglass-ceramics

- ♠ clinical applications
  - ⇒ bone spacer
  - ⇒ coatings
  - ⇒ composites
  - ⇒ distance-keeping implants in osteotomy
  - ⇒ artificial vertebras
  - ⇒ dental implants







glass-ceramic implants of Bioverit® I

bioresorbable bioceramics

♠ systems

⇒ ß-TCP (ß-tri calcium phosphate)

⇒ phosphate glasses and glass-ceramics

♠ properties

⇒ high biocompatibility

⇒ controlled resorption or biodegratation

⇒ low chemical resistance

⇒ poor mechanical strength

♠ clinical applications
(powder, porous solid, dens solid)

⇒ bone void filler

coatings with bioactive ceramics

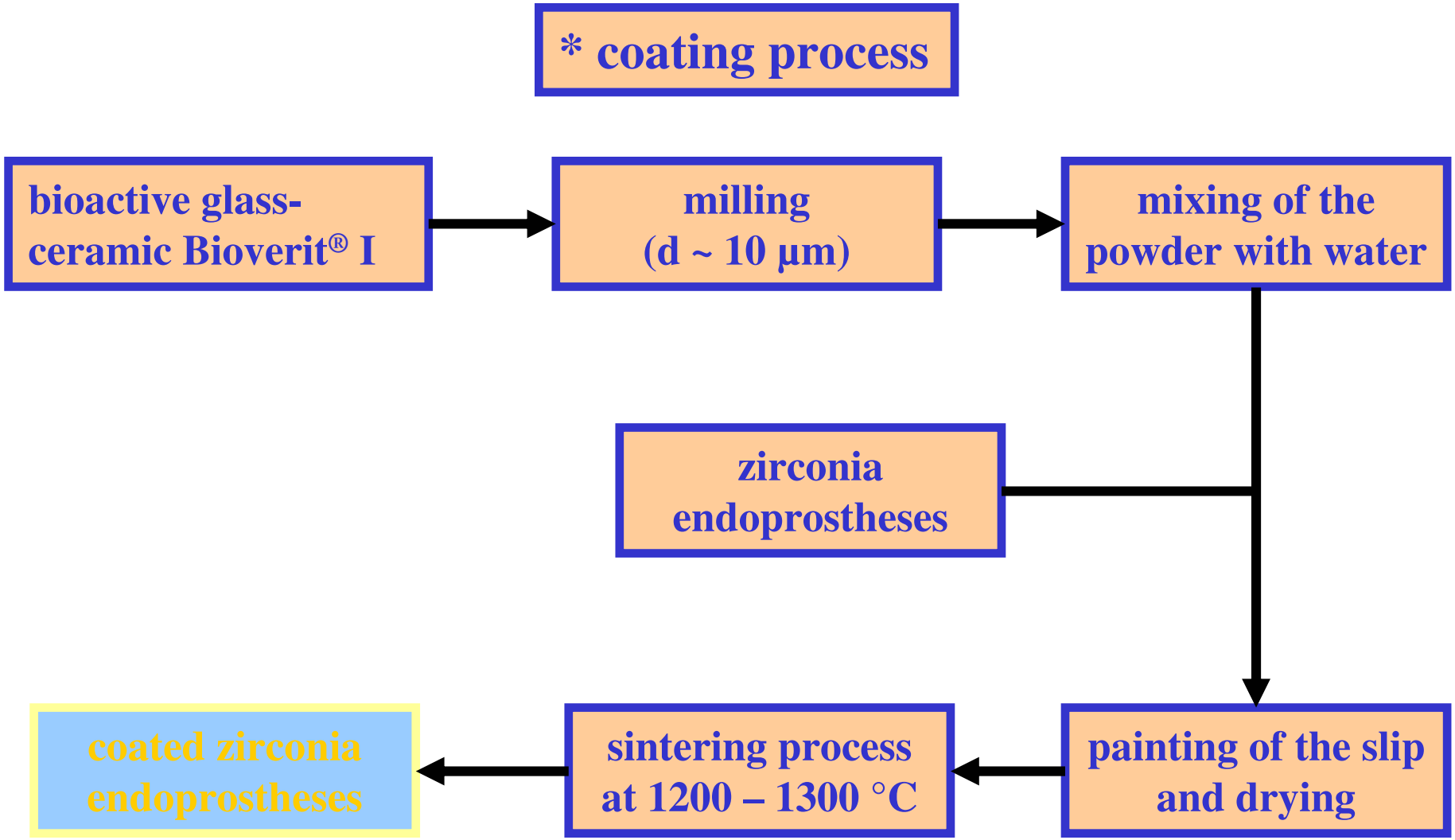
*** technology:**

⇒ plasma spraying
⇒ sputtering
⇒ sol-gel-process
⇒ sintering

*** requirements:**

⇒ good biocompatibility, bone bonding
⇒ similar thermal expansion coefficients
⇒ high chemical stability
⇒ good adhesive strength of the coating
⇒ no changes of the substrates by the coating process

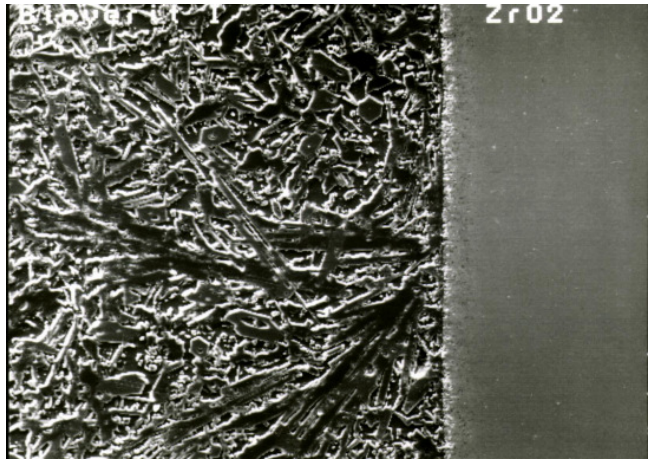
Bioverit® I coating on Moje zirconia prostheses



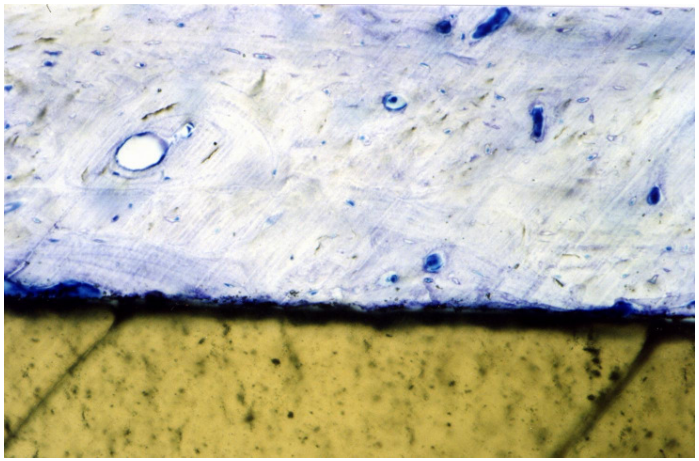
Bioverit® I coating on Moje zirconia prostheses

* results

⇒ good biocompatibility, bone bonding ability
⇒ dense and crack-free layer
⇒ long term stability
⇒ good adhesive strength of the coating
⇒ no changes of the zirconia ceramic



microstructure of the coating,
scanning electron micrograph



intergrowth of coating and bone,
optical photomicrograph

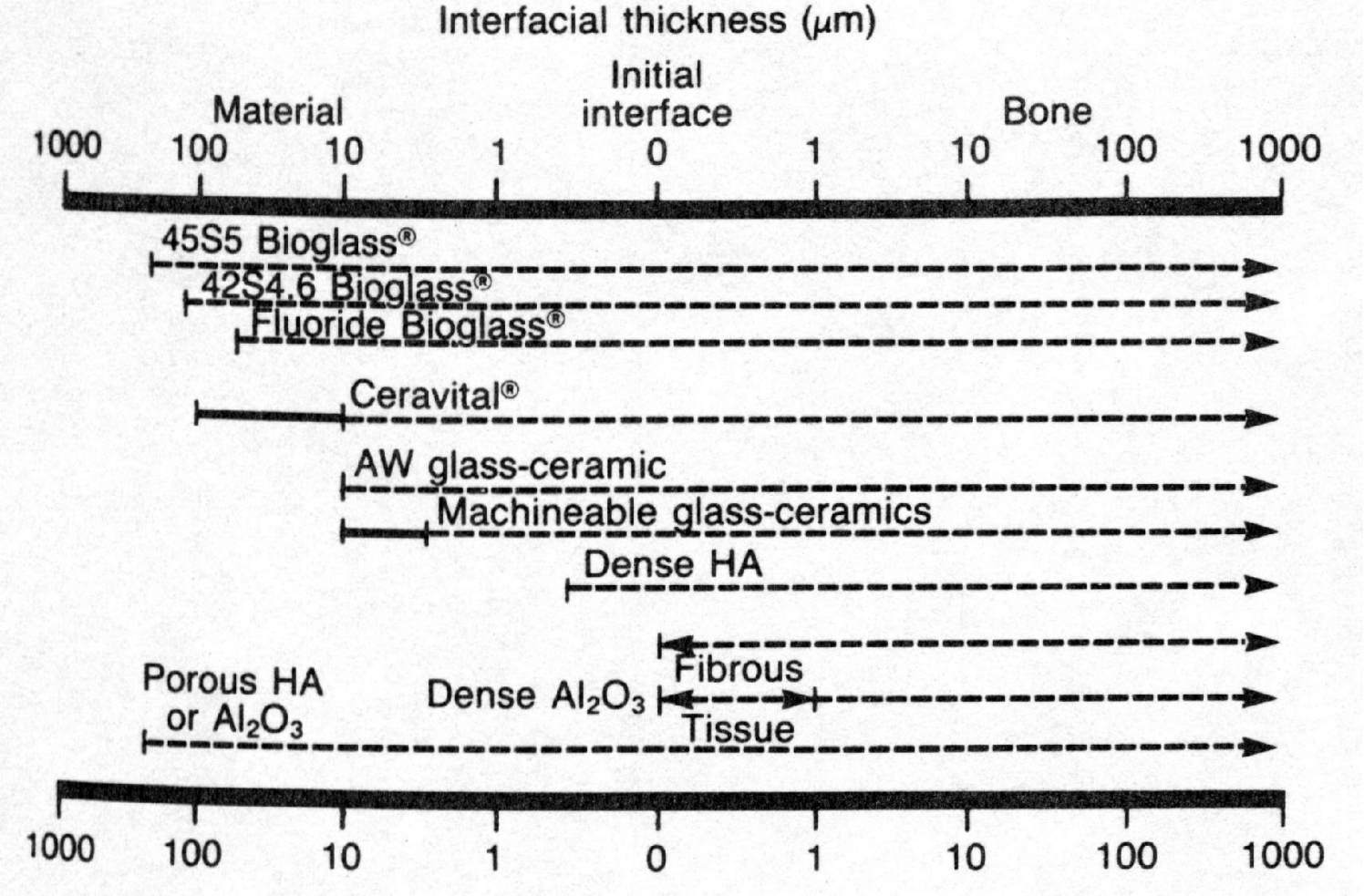
summary

⌦ **Bioceramics:**

- ⇨ **wide range of biological properties**
- ⇨ **different chemical compositions**
- ⇨ **various chemical and mechanical properties**
- ⇨ **different shape and size**
- ⇨ **wide range of clinical applications**

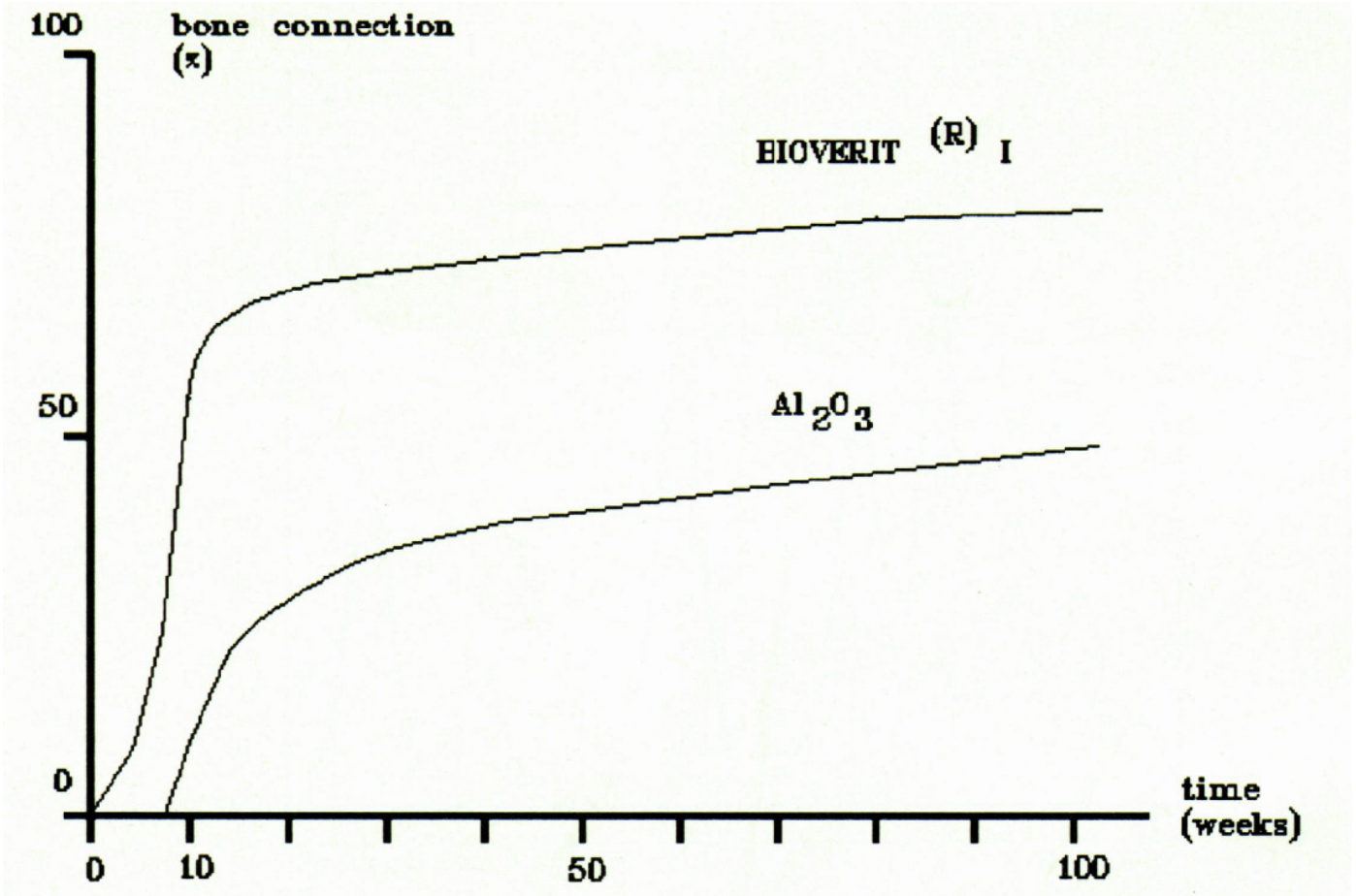
Ergänzungsfolien

bioceramics – interface range



bioactive bioglass-ceramic Bioverit® I

bone connection



bone connection in dependence of the time of implantation in an animal experiment – glass-ceramic Bioverit® I implants in comparison to corundum implants