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Titanium in dental prosthetics II
Studies and developments

John E. Tibballs

Potential for improvement

- Alloy improvement
  - more strength for larger prostheses
  - less stiff to give better retention
  - stable during porcelain firing;
- Better milling techniques
  - support/compensation for low stiffness
  - coolants for better finish
  - tooling technology for quicker fabrication

Titanium alloy design criteria

increase strength	approx. 600 MPa
reduce elastic modulus	approx. 80 GPa
withstand porcelain firing	stable at 800°C
reduce galling	hard at 700°C

Learning from orthopaedics I

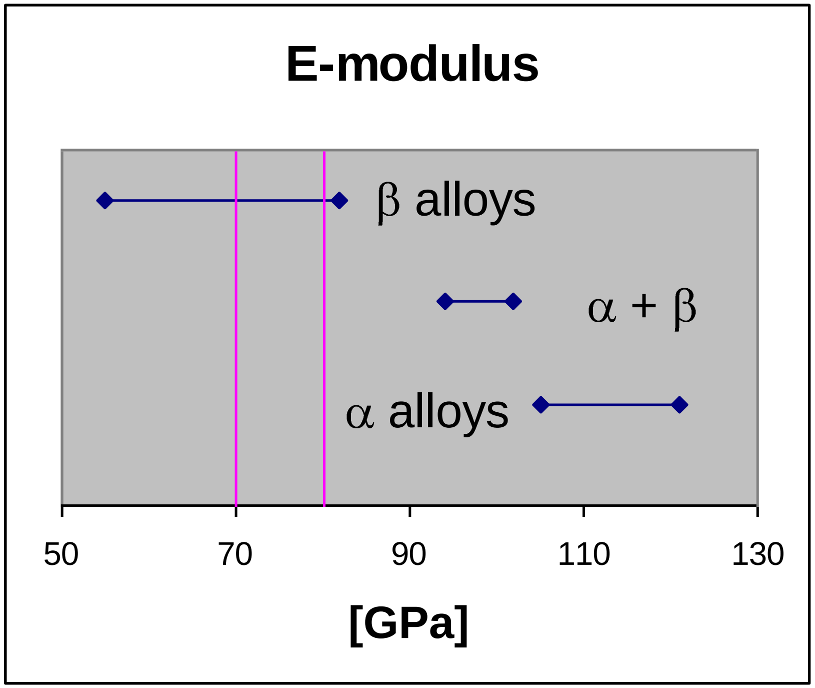
- 40-years with titanium orthopaedic implants
- Major problem is wear
  - not an issue for dental prosthetic frameworks
- Not customised
  - can use optimal alloy fabrication methods
- Not fired, but coated or sandblasted
  - retain properties from fabrication

Learning from orthopaedics II

- 7 types of titanium for surgical implants have ISO standards (ISO 5832-2; -3; -11; -14)
  - Grades I to IV of commercial purity (CP) Ti
  - Grade V (Ti-6Al-4V)
  - Ti-6Al-7Nb (Protasul-100)
  - Ti-15Mo-5Zr-3Al
- NB! Alloying with aluminium is accepted

Strategy for improvement

Aim: reduce E-modulus to 70-80 GPa



For elastic match to tooth and veneer

β-Ti alloys would be preferable.

Strategy for alloys without Al

Aim: increase strength by 150-250 MPa

- Solid solution strengthening (milling & casting alloys)
- Promote mixed dual-phase $\alpha + \beta$ (milling alloys)
  - avoid brittle martensite α' formation
- Fully β alloys are intrinsically much softer
  - need lot of alloying

Element	V	Zr	Mo	Nb	Ta
MPa/wt%	19	15	27	22	15
Min. for full β	14	> 22	10	> 20	-

Advanced candidate alloys

Name	Composition	Type	YS [MPa]	Elong. [%]	E [GPa]
TMFZ	12Mo-6Zr-3Fe	β	1000	19	80
TNTZ	35Nb-5Ta-7Zr	β	530	15	55
TNTZO	35Nb-5Ta-7Zr +0.4O	β	960	12	66
Grade V	6Al-4V	near α	925	17	110
"JIS"	15Zr-4Nb-4Ta	α + β	800	20	94
"Tiqq"	15Zr	α + β	620	12	102

Adapt milling techniques

- Reduce milling force
  - take longer – smaller cuts
  - coated or CBN tooling
  - rotating tool, manipulate workpiece (5-axis)
- Reduce temperature
  - better lubricant
  - chill coolant
- Avoid grinding forces
  - EDM

Tooling

- CNB (carbon-boron-nitride) or ceramic-coated tooling
  - rapidly rotating tools
  - grinding not cutting

Lubrication

- Coolant / lubricant
  - largely water (preferably chilled)
  - esters to wet the metal
    - mineral oil
      - saturated fats
      - waste disposal cost
    - vegetable/animal oils
      - usaturated fats
      - break down / turn rancid

Milling strategy

- Fully supported work piece
  - work piece much larger than prosthesis
  - retain supports to work piece
- CAD/CAM strategy
  - mill internal surface of coping/pontics first
  - compensate for low elastic modulus when walls of coping/pontics are thin
  - consider EDM to remove supports

EDM

- Electric-Discharge Machining (Spark erosion)
  - no mechanical force on workpiece
  - no lubricant
  - dielectric coolant

Milled *versus* cast titanium

CP and advanced alloys	only CP titanium
no α-case	α-case to be removed
CAD/CAM equipment	arc-melting equipment
CNC	hand crafted
surface preparation?	sandblasting
porcelain firing ?	known bonding agents

Milled titanium *vs* zirconia

	Milled titanium	Milled / sintered zirconia
Accuracy	**	*
Elasticity to match veneer (65 GPa)	110 – 115 GPa	185 GPa
Thermal expansion	$9.1\text{-}9.4 \cdot 10^{-6}$	$10.6 \cdot 10^{-6}$
Esthetics	metallic grey	white or shaded
Removal / repair	clip over / laser weld	break up / discard

Conclusions

Titanium milling

- permits use of advanced alloy fabrication
- requires substantial investment in equipment
  - fully adapted CAD/CAM
  - full prosthesis capacity
  - lubricant / coolant disposal
- studies needed into surface preparation and porcelain firing

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