



Long-Term Clinical Performance of Fixed Dental Prostheses Depends on Alloy Selection

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Dr. Ivar A Mjor

Long-term clinical studies



Practice-Based-Research-Network Clinical Trials

- Cl. II amalgams 10 years
Jokstad & Mjor, Acta Odontol Scand 1985, 1989ab, 1990, 1991 → PhD 1992
- Cl. II glass-ionomers 5 years
Mjor & Jokstad, J Dent 1993
- Cl. III/IV composite resins 10 years
Jokstad, Mjor, Nilner, et al. Quintessence Int 1994



Study 1: RCT, 10+ years

Dr. Ivar A Mjor

PBRN Clinical Studies organized by NIOM

- Cl. II amalgams 10 years
- Cl. II glass-ionomers 5 years
- Cl. III/IV composite resins 10 years

Luting Cements

Ten years' clinical evaluation of three luting cements
A. Jøkstad and I. A. Mjor*
Department of Prosthodontics, Dentistry and Stomatognathic Physiology, University of Oslo, Oslo, Norway, and NIOM, Scandinavian Institute of Dental Materials, Haslum, Norway

Jokstad & Mjor, J Dent 1996



Dr. J Valderhaug (+1999)

Study 2: Prospective cohort 25+ years

Journal of Dentistry, Vol. 25, No. 2, pp. 91-100, 1997
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Assessment of the periapical and clinical status of crowned teeth over 25 years

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ABSTRACT
Objectives: The purpose of this study was to examine radiographically changes in the periapical status and compare the clinical status of teeth with a vital pulp and root-filled teeth restored with crowns and bridge retainers during 25 years.
Methods: During 1967/68, 114 patients received prosthodontic treatment by senior dental students at the Oslo Dental Faculty. In all, 291 teeth with a vital pulp and 106 root-filled teeth were restored with 158 prostheses. All root-filled teeth were restored with a cast dowel and core. The casts were made in a type-3 gold alloy, and cemented with zinc phosphate cement. Forty-six teeth were restored with crowns and 251 teeth with bridge retainers. <http://dx.doi.org/10.1054/jdent.1997.25209>

Study 3: Retrospective Cohort study, 10-20+ years

2604 A retrospective 19 years study of Chrome-Cobalt vs. Gold-alloy Implant Superstructures

K. TEIGEN, University of Oslo, Norway, and A. JOKSTAD, University of Toronto Faculty of Dentistry, Canada

Background: Chrome-cobalt alloy for intra-oral reconstructions has been available for some time. It can be hypothesized that the incidence and type of mechanical defects of intracoral prostheses made from chrome-cobalt will differ from those made from gold-alloys over time due to the differences in physical properties, such as a higher modulus of elasticity, hardness and corrosion resistance. Objectives: A fairly extensive patient group restored with implant-supported prostheses and closely monitored over 20 years enabled a retrospective study to test the null hypothesis that the use of chrome-cobalt has no benefits compared to a traditional gold-alloy. Methods: In the period between 1987 and 1996, 300 patients received implant-supported crowns, partial- or full dentures made from either chrome-cobalt or gold-alloy and veneered with a ceramic or acrylic in a specialty clinic in Tromsø, Northern Norway. These were supported by 1200, principally Brånemark® standard or Mark 2 (NobelBiocare, Gothenburg, Sweden) and Astra (Astra Tech, Gothenburg, Sweden) dental implants. All implants had been placed following the standard two-stage surgical protocol. A chart auditing and radiographic interpretations were done by a clinician unfamiliar with the clinic. The complete treatment history pertinent to the implant prosthesis since placement was recorded, with special focus on recording fractures of the metal substructure and/or the ceramic veneer. The outcomes and statistical comparisons were considered both on the patient level and on the implant level. Results: A wide range of different maintenance problems were noted, but there were no differences with regard to implant survival, and prevalence of maintenance needs and superstructure prognosis as a function of using chrome-cobalt and gold-alloy for the intra-oral reconstruction. Conclusion: Implant survival as well as maintenance and prognosis are similar for implant-supported reconstructions made in chrome-cobalt and gold-alloy veneered with ceramic or acrylics. Acknowledgment: This study has been funded by University of Oslo.

See #273 - Denture Research: Clinically Based Research


10:45 AM-12:00 PM, Saturday, March 24, 2007 Ernest N. Morial Convention Center Exhibit Hall 12-3

Back to the Prosthodontics Research Program

Back to the IADR/AADR/CADR 85th General Session and Exhibition (March 21-24, 2007)

Top Level Search

Summary, own clinical studies

	Placed	Material combination	% Technical/ Mechanical complications	Types Technical/ Mechanical complications
Valderhaug et al. J Dent 1997	1967-68 114p →32p	Gamma, KAR (Type 3 Au alloy) + Hue-lone (Heat-cure acrylic)	10% after 25 yrs	
Jokstad & Mjor J Dent 1996	1983-85 61p→40p	"Metal-Ceramic" or "Gold-Acrylic" casting alloy	5% after 10 yrs	None. 31/135 retainers failed (predominant caries)
Teigen & Jokstad COIR 2011	1987-95 198p	Co-Cr (Bego + Biodent/V-classic/Synspar) (ceramic) / Type 3 Au alloy + SR-Isosit (Heat cure acrylic) / Isosit (acrylic teeth)	8+units with adverse event rate >0.4/yr (n=41): Co-Cr-cer: 8% Au-Acryl.: 35%	Co-Cr -ceramic 1. fracture/ loosening Co-Cr- /Au- acrylic: 1. wear/surface fractures/esthetics. 2. fracture/ loosening

Reflections following analyses of data from these 3 long-term clinical studies

1. It would be reasonable to assume that the FDP framework alloy will determine the long term clinical performance

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2. When, and how do differences in properties of alloys become clinically manifest, and can these appear as clinical deficiencies?

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Reflections following analyses of data from these 3 long-term clinical studies

1. It would be reasonable to assume that the FDP framework alloy will determine the long term clinical performance
2. When, and how do differences in properties of alloys become clinically manifest, and can these appear as clinical deficiencies?
3. **What is the current documentation of the question in the dental literature?**

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Quest for information

1. Which metallic materials are currently available on the market for fabricating FDP frameworks?
2. How do these materials perform over time?
3. What clinical data are available for establishing the long term clinical performance of FDPs as a function of FDP design and biomaterials combinations?

Quest for information

1. Which metallic materials are currently available on the market for fabricating FDP frameworks?

Dental Casting alloys

Traditional Classification from 1932

TYPE	HARDNESS	USE
I	SOFT	Single surface restoration
II	MEDIUM	Inlays, onlays
III	HARD	Onlays, crowns, Short span FDPs
IV	EXTRA HARD	Post/cores; Long span FDPs, RPDs



1960 1970 1980 1990 2000 2010

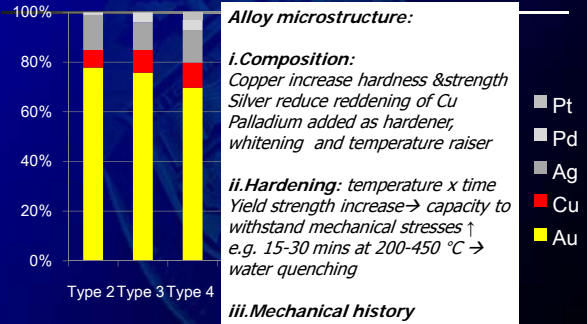
Gold casting alloy+Acrylic FDPs

- Highly successful periodontal-prosthetic FDPs with 20 years+ clinical follow-ups
- Göteborg University, Sweden
- Type 3 Au alloy+ Acrylic Resin



Restored 1969/73. Reports by: Nyman & Lindhe & Lundgren 1975a,b 1976a,b,c 1977...1984

Dental casting alloys, since early 40ies



Alloy microstructure:

i. Composition:

Copper increase hardness & strength
Silver reduce reddening of Cu
Palladium added as hardener, whitening and temperature raiser

ii. Hardening:

temperature x time
Yield strength increase → capacity to withstand mechanical stresses ↑
e.g. 15-30 mins at 200-450 °C → water quenching

iii. Mechanical history

+ Indium, Tin, Iron, Zinc, Gallium etc.
Fine grain: Iridium, Ruthenium, Rhenium

Ceramic veneering of casting alloys

Metal-ceramic alloys; new requirements:

- Higher fusion temperature: 165-280° C higher than the ceramic sintering temperature
- Coefficient of thermal expansion near that of ceramic ($7-8 \times 10^{-6}/^{\circ}\text{C}$)
- The ability to form an oxide layer to provide a strong bond to the ceramic

Au-alloy (Acrylic)

1956/1963: Au-Pt-Pd



1960 1970 1980 1990 2000 2010

Ceramic veneering of casting alloys



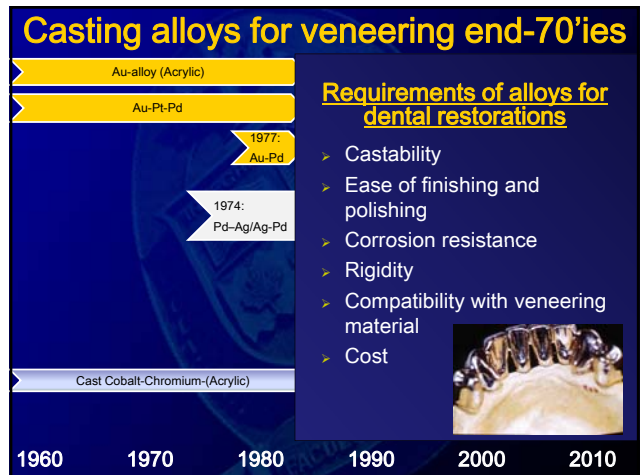
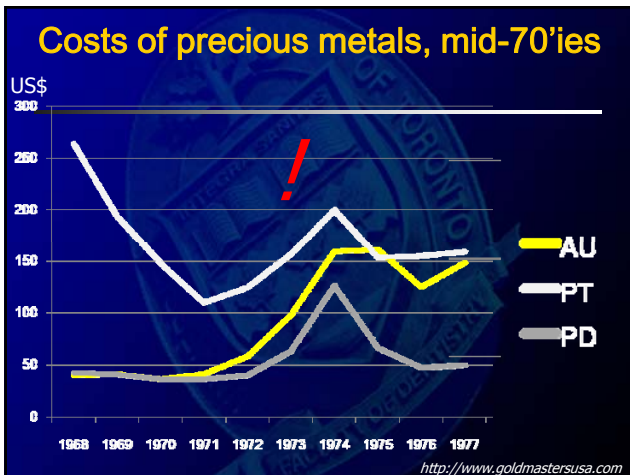
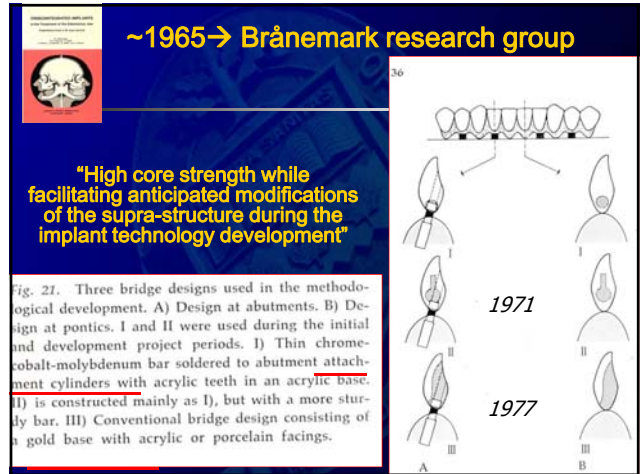
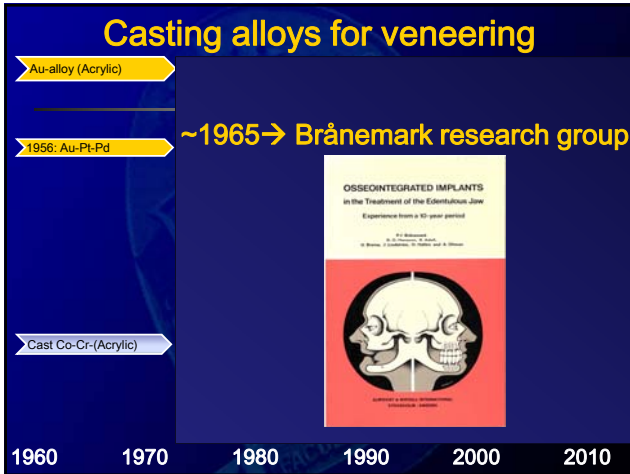
• Casting Temp 1260°C → prone to temperature distortion ("Sag") when sintering the ceramic

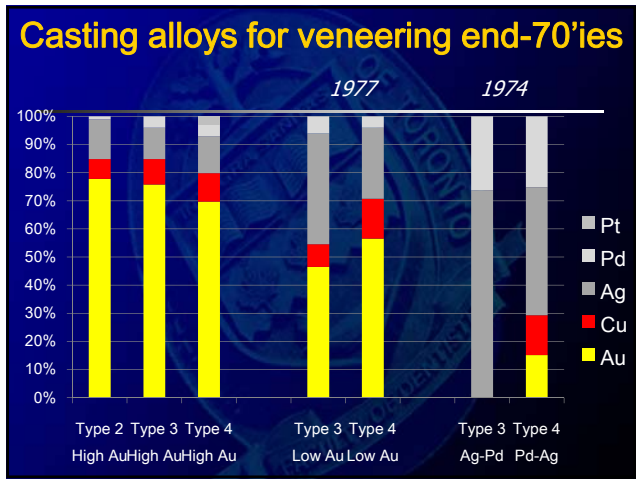
- Hardness relative low
- Yield strength relative low
- Stiffness relative low
- Ductility relative low
- Density 18-19 → "heavy"

- Not full ceramic coverage if >3 units
- Facial ceramic veneer (only)



Ag
Pt
Pd
Au





iFDPs (made in Sweden)

- Co-Cr phased out and replaced by type-3 Au alloy
- No scientific data or rationale reported in the literature
- Due to concerns in Sweden about "oral galvanism" / electrochemical incompatibility of alloys?

Prosthodontic SOPs developed by Drs. PO Glantz, B Hedegård, G Carlsson

Co-Cr Adell et al. IJOMS 1981

Type 3 Au-a. Adell et al. IJOMS 1981

Type 3 Au-alloys+ Acrylic teeth have stood the test of time!

20 years post-i.-placement. Lindquist & Carlsson 1979 → Ekelund et al. IJP 2003

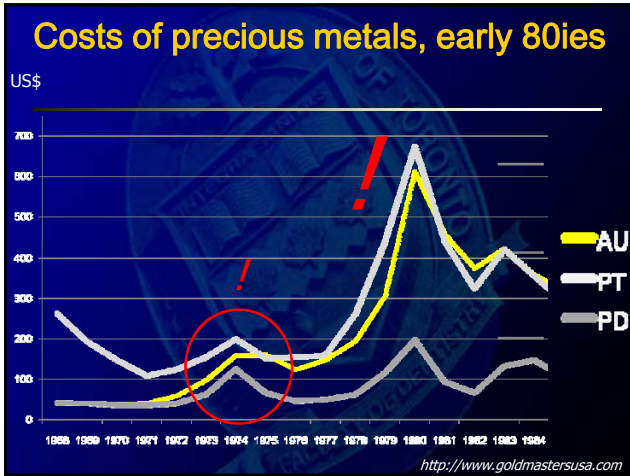
Cantilevers have consistently since the 70ies been made in Scandinavia to create 10-12 FDP units

From original patient cohort (Haraldson & Carlsson. Swed Dent J 1979)

iFDPs (made in Toronto)

- Contain Cost
- Silver-Palladium cast alloy
 - Albacast® → Palliag M® (Type 3→4)
- Prefabricated teeth
- Precision of fit Ag-Pd vs Co-Cr (Cox/Chao/Zarb 1985/88)

(Zarb & Symington JPD 1983)



Alloys for veneering → ceramics

1960 1970 1980 1990

- Au-alloy (Acrylic)
- Au-Pt-Pd
- 1977: Au-Pd
- Au-Pd-Ag
- 1974: Pd-Ag (+/-Sn)
- Pd (- Ag)
- Pd-Ag-Au
- Pd-Cu
- Pd-Ga
- Ag-Pd
- Cu-Al
- Cast Cobalt-Chromium-(Acrylic)
- Cast Co-Cr
- Ni-Cr (+/- Be)

Refinements of fabrication methods

- Coefficient of thermal expansion compatibility
- Cast distortion – cast size vs soldering
- Cast surface roughness
 - Equipment
 - Casting Procedure
 - Increase/Decrease speed & maximum /minimum heat & pressure
 - Investment – Chemistry, Water : Powder Spruing

Alloys for veneering → metal-ceramic

1960 1970 1980 1990

- Au-alloy (Acrylic)
- Au-Pt-Pd
- 1977: Au-Pd
- Au-Pd-Ag
- 1974: Pd-Ag (+/-Sn)
- Pd (- Ag)
- Pd-Ag-Au
- Pd-Cu
- Pd-Ga
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- Cu-Al
- Cast Cobalt-Chromium-(Acrylic)
- Cast Co-Cr
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+ base metal alloy systems enters the market

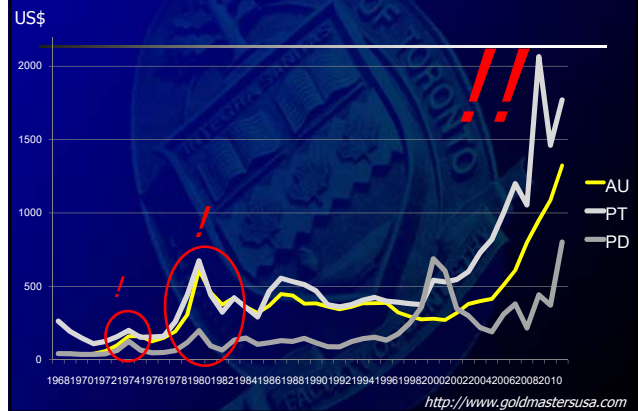
Cobalt-Chrome – Ceramic

From: Kourkouta et al. Br Dent . 2007

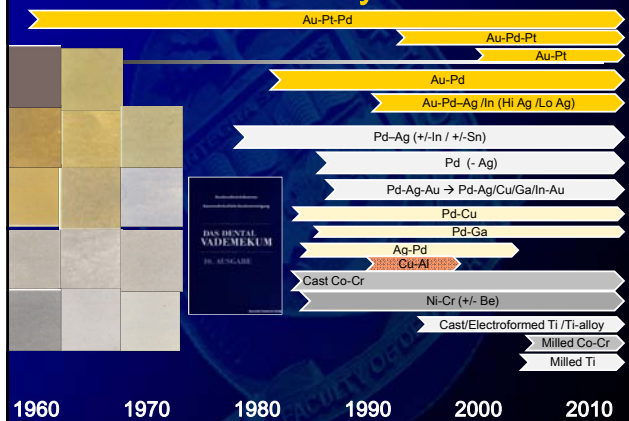
Base vs Noble metal casting alloys

- Higher fusion and casting temperature
- Phosphate bonded investment - more complex and less controllable than gypsum bonded investment systems.
- Potential for excessive oxide formation
- Hardness → more difficult finishing & polishing
- Fit of the casting less predictable (investment procedures)
- Procedures for improving or modifying less than clinically acceptable margin adaptation / fit less predictable
- + Modulus of elasticity 2x gold-alloys
- + Less framework distortion during porcelain firing
- + Resistance to tarnish by formation of surface monolayer of Cr-oxide

Costs of precious metals, 2011



Metal-ceramic alloys anno 2011



Quest for information:


1. Which metallic materials are currently available on the market for fabricating FDP frameworks?
2. How do these metallic materials perform over time?



Recent Systematic Reviews, Clinical performance of FDPs

- Ionnaidis ea. (Teeth) J Dent 2010
- Zurdo ea. (Implant) COIR 2009
- U Bern: Aglietta/Brägger/Jung/Lang/Lulic/Pjetursson/Tan ea. (Implant/Teeth) COIR 2004a,b,2005,2007,2008,2009
- Sailer ea. (Implant) COIR 2007
- Goodacre ea. (Teeth/Implant) JPD 2003a,b

None of these identified failures/outcomes in terms of alloy composition



Academy of Osseointegration. State of the Science in Implant Dentistry Conference August 2006

SECTION 5

Does the Type of Implant Prosthesis Affect Outcomes for the Completely Edentulous Arch?

S. Ross Bryant, DDS, MS, PGP/
David MacDonald-Jarvis, BDS, LLB, MSc, FDSRCS(Ed), GDCRCP/Avonmoun, DMD, MS, PhD

SECTION 6

Does the Type of Implant Prosthesis Affect Outcomes in the Partially Edentulous Patient?

Helle Peter Jensen, DMD/Caroline Svanberg, DDS, MS, PGP

Conclusion: cemented versus screw-retained restorations. Little to no usable information was available on restorative materials and their influence on the outcome. Most of the studies were conducted in an institutional environment, which is representative of dental schools.

Conclusion: success in implant dentistry and success outcomes between fixed and removable prosthesis types in edentulous arches. The possible effects of other variations in prosthetic type (such as splinting, rotational characteristics, prosthetic materials, and the number of implants) as well as the effect on crestal bone loss and prosthesis success and maintenance outcomes, are not addressed in detail in this paper. As most commonly reported in implant outcome studies,

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The optimal design for an FDP?

- Excellent marginal fit
- Withstand occlusal forces
- Minimal biofilm formation
- Access for oral hygiene
- Satisfactory aesthetics

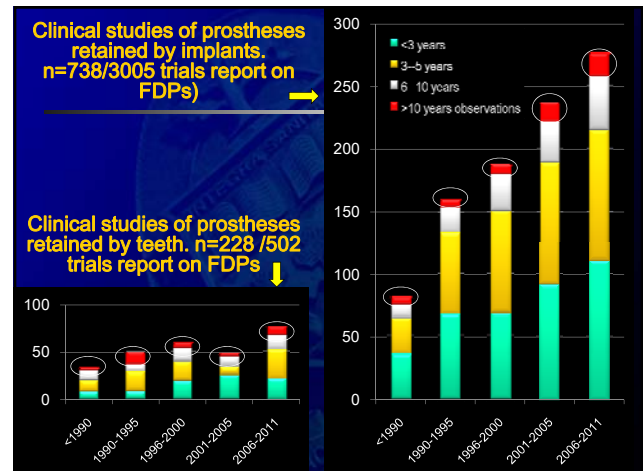
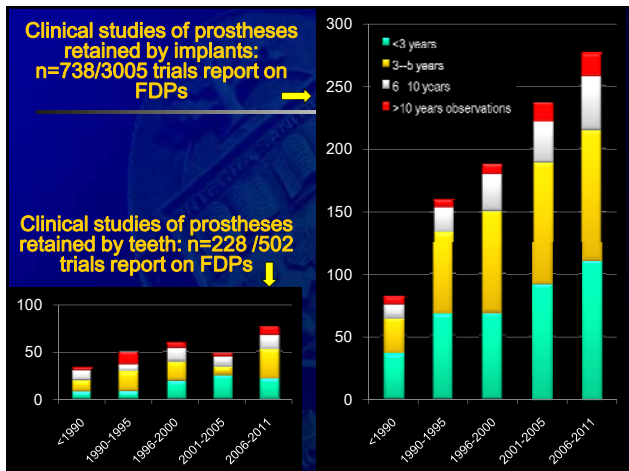
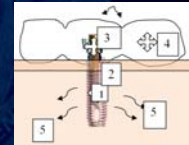


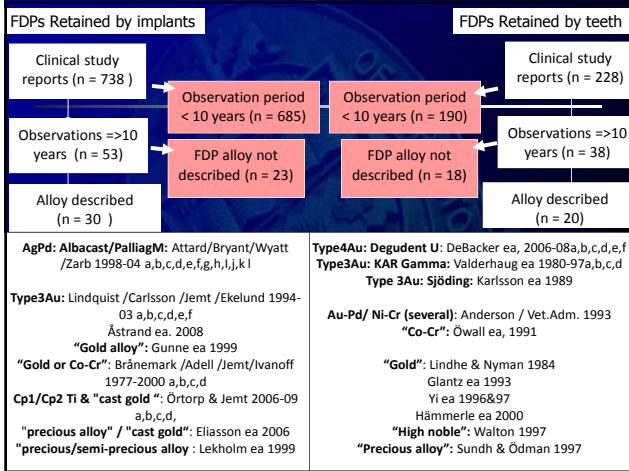
Guidelines for optimizing the FDP design are mostly empirical

- Favourable distribution of retainers (teeth or implant)
- Framework connectors minimum 5 mm height x 4 mm width
- Freedom in centric occlusion
- Even anterior and posterior occlusal contacts
- Maxillary anterior palatal surfaces shaped to create axial load direction and to guide lateral movements
- Minimal anterior overbite and overjet
- Posterior occlusion shaped to guide occlusal forces in axial directions
- Limited steepness of cuspal inclines
- No contacts on cantilevers
- If tooth-retained, vital teeth, especially if retaining a cantilever

Further research for optimizing design of implant-retained FDPs?

- Major emphasis on laboratory studies
- Focus on casting precision and fit to implant platforms
- Biomechanical model estimates of how supra-structure loading generate stress in:
 1. the implants
 2. the implant system components
 3. the abutment(s)
 4. the framework
 5. the bone
- Hardly any biomechanical theories have been confirmed by clinical outcomes (Bryant et al. 2007).





Our current understanding of optimal choice of FDP design and biomaterial selection should perhaps be reconsidered because of:

1. vertical space
2. cantilevers

At UoT our edentulous patients in 2011 are different from the ones in 1980

10.2.1980, case B8756, Study 1

"...edentulous for at least 5 years" (Zarb et al. 1983)

Many of our edentulous patients today are not similar anatomically to the average patients treated in 1980

The average edentulous patient 2010

The average edentulous patient 1980

Vertical space increases with period of edentulousness

Zarb et al. 1983: "edentulous for at least 5 years"
 Quirynen/Naert/vanSteenberghe 1982-89: "period of edentulousness 0-25 yrs"
 Meijer/Visser/Raghoobar 1998: "mean edentulous period 21yrs"

Some supra-structures require much vertical space due to bulk



Cantilever risk confusion - SRs published in 2009:

1. Aglietta et al. Clin Oral Implants Res 2009: "*<<short span>> ICFDPs represent a valid treatment modality; no detrimental effects can be expected on bone levels due to the presence of a cantilever extension per se*"
2. Zurdo et al. Clin Oral Implants Res 2009: "*The incorporation of cantilevers into implant-borne prostheses may be associated with a higher incidence of minor technical complications*"

Few studies were identified and critically appraised

Stress and deformation of a FDP

- A beam with a *regular geometric body* deform upon *central vertical loading* predictably:

$$D = \frac{F}{E} * \frac{L^3}{W * H^3} * \text{Constant}$$

F: vertical loading
E: modulus of elasticity
D: vertical deformation
L: length W: Width H: Height

- Often applied to intra-oral FDP designing
- Available 3-D space intra-orally is self-limiting
- Determined by the maxilla-mandible anatomy and -vertical relationship



Stress and deformation of a FDP with a cantilever

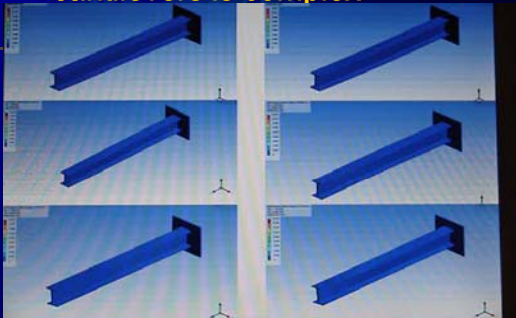
- Introduce additional vertical and rotational force vectors in the structure and retainers
- Force vectors vary with location, magnitude and direction of the point loading
- Estimating the bending of FDP cantilevers is complex, even for regular geometric bodies

Estimating the bending of regular form cantilevers is complex

Vertical bending

Lateral bending

Torsional bending



Without - With a plastic hinge state

For free, harmonic vibrations the Timoshenko-Rayleigh equations take the form

$$EI \frac{d^4 \hat{w}}{dx^4} + m\omega^2 \left(\frac{J}{m} + \frac{EI}{kAG} \right) \frac{d^2 \hat{w}}{dx^2} + m\omega^2 \left(\frac{\omega^2 J}{kAG} - 1 \right) \hat{w} = 0$$

From: wikipedia.org

Stress and deformation of the supra-construction with cantilevers

Additional vertical and rotational force vectors

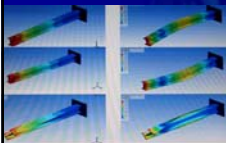
Location, magnitude and direction of the point loading?

Theoretical estimation of cantilever bending is complex

In irregular geometric bodies made from different materials the interactions complexity between point loads and force vectors increases further - are mathematical estimations at all possible?

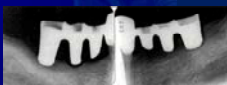


Cantilevers - theory and practice?



Öwall et al. Int J Prosth 1991
(n=11, 1-20+ yrs)

-
Co-Cr + acrylic teeth
Placement 1968
3/11 framework fractures



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Final reflections after reviewing our current evidence for clinical practice

1. Innovative procedures for machining/laser-welding/-sintering dental alloys +/- CAM instead of traditional casting will expand the range of products in the market further

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2. We don't know how most dental alloys that currently are prescribed by dentists perform clinically over time, nor range of possible or optimal FDP design as a function of alloy

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Final reflections after reviewing our current evidence for clinical practice

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2. We don't know how most dental alloys that currently are prescribed by dentists perform clinically over time, nor range of possible or optimal FDP design as a function of alloy
3. Authors and editors must have a shared responsibility to describe biomaterials and design details in clinical investigation reports

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