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

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Faculty of Dentistry, Toronto, Canada

Long-term clinical studies

Dr. Ivar A Mjor

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

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Ten years' clinical evaluation of three luting cements

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Department of Prosthetic Dentistry and Stomatognathic Physiology, University of Oslo, Oslo, Norway, and NIOM, Scandinavian Institute of Dental Materials, Haslum, Norway

Jokstad & Mjor, J Dent 1996

Study 2: Prospective cohort 25+ years

Dr J Valderhaug (†1999)

PII: S0300-5712(96)00008-5
Journal of Dentistry, Vol. 25, No. 2, pp. 97–105, 1997
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Assessment of the periapical and clinical status of crowned teeth over 25 years

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Department of Prosthetic Dentistry and Stomatognathic Physiology, Dental Faculty, University of Oslo, Oslo, Norway

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 351

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

2604 A retrospective 19 years study of Chrome-Cobalt vz.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 intraoral 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 ceramics or acrylics 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 unaffiliated 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 ceramics or acrylics. Acknowledgment: This study has been funded by University of Oslo.

Seq #273 - Denture Research: Clinically Based Research
10:45 AM-12:00 PM, Saturday, March 24, 2007 Ernest N. Morial Convention Center Exhibit Hall I2-J

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

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?**

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?**

9

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?

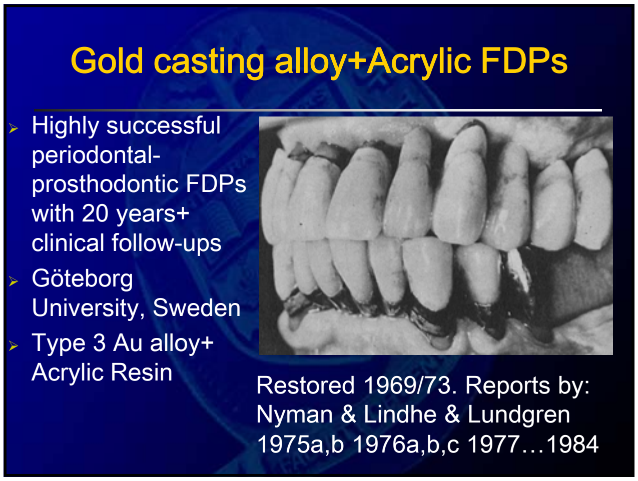
Dental Casting alloys

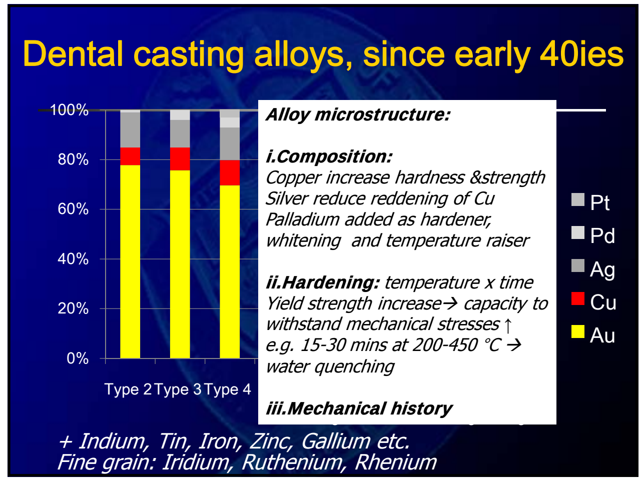
Au-alloy
+
(Acrylic)

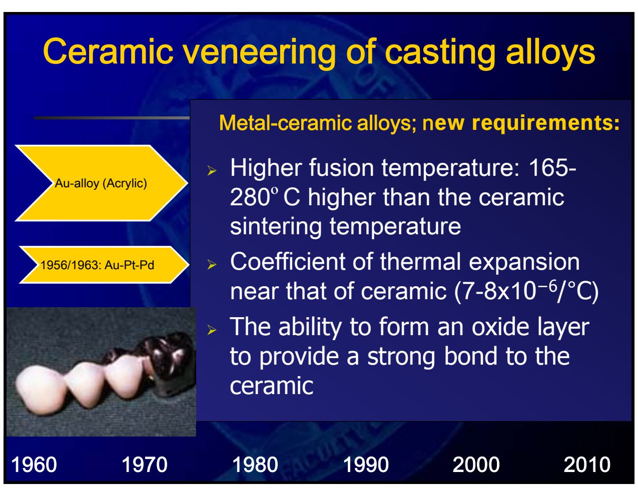
Traditional Classification from1932

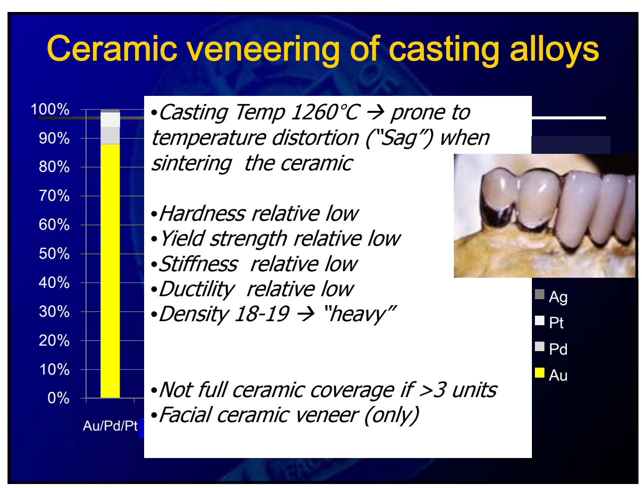
TYPE	HARDNESS	USE
I	SOFT	Single surface restoration
II	MEDIUM	Inlays, onlays
III	HARD	Onlays, crowns, Short span FDPs
IV	EXTRA HARD	Post/cores; Long span FDPs, RPDs

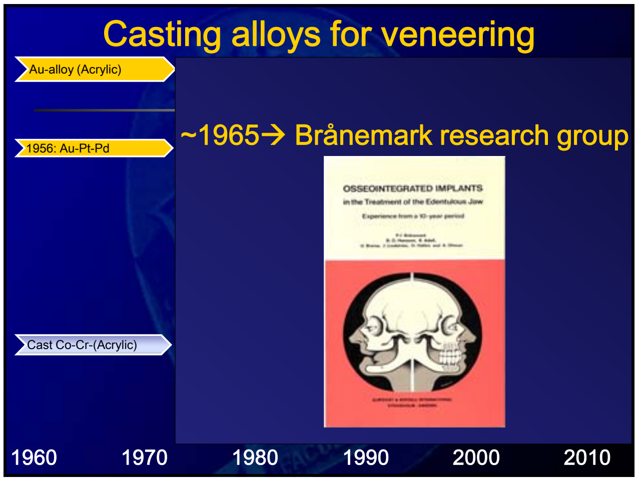
1960 1970 1980 1990 2000 2010

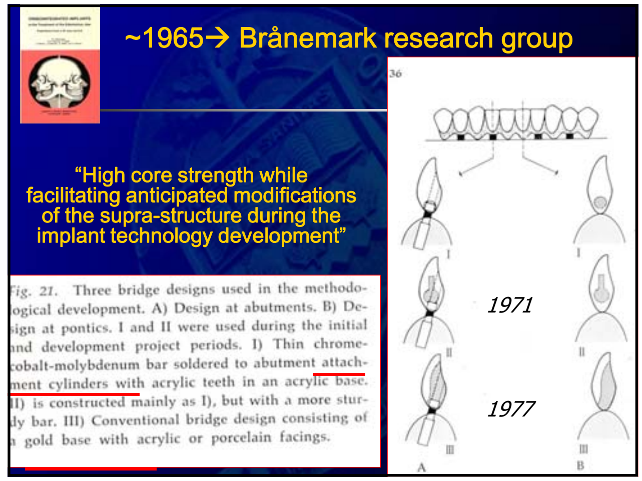

Gold casting alloy+Acrylic FDPs
Highly successful periodontal-prosthodontic FDPs with 20 years+ clinical follow-ups
Göteborg University, Sweden
Type 3 Au alloy+ Acrylic Resin
Restored 1969/73. Reports by: Nyman & Lindhe & Lundgren 1975a,b 1976a,b,c 1977…1984

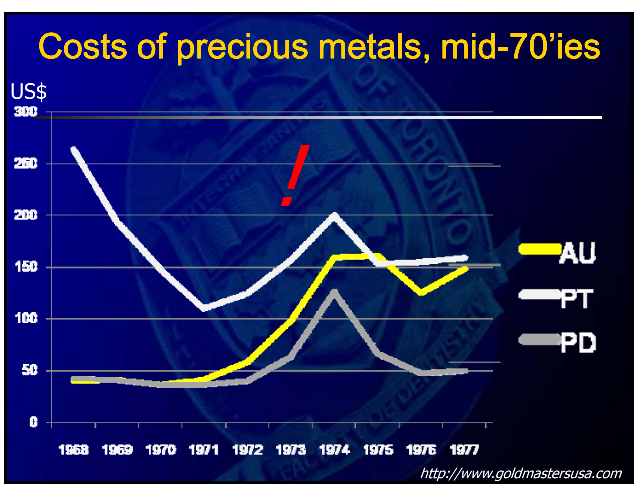

Dental casting alloys, since early 40ies
100%
80%
60%
40%
20%
0%
Type 2
Type 3
Type 4
Alloy microstructure:
i.Composition:
Copper increase hardness &strength
Silver reduce reddening of Cu
Palladium added as hardener, whitening and temperature raiser
ii.Hardening: temperature x time
Yield strength increase→ capacity to withstand mechanical stresses ↑
e.g. 15-30 mins at 200-450 °C → water quenching
iii.Mechanical history
Pt
Pd
Ag
Cu
Au
+ Indium, Tin, Iron, Zinc, Gallium etc.
Fine grain: Iridium, Ruthenium, Rhenium

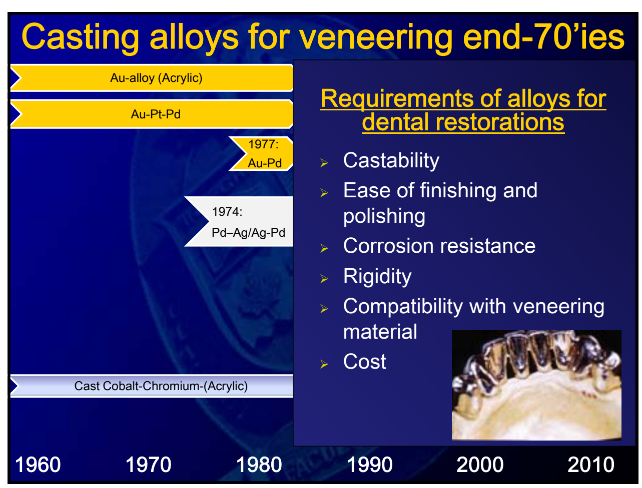

Ceramic veneering of casting alloys
Au-alloy (Acrylic)
1956/1963: Au-Pt-Pd
Metal-ceramic alloys; new requirements:
Higher fusion temperature: 165-280° C higher than the ceramic sintering temperature
Coefficient of thermal expansion near that of ceramic (7-8x10⁻⁶/°C)
The ability to form an oxide layer to provide a strong bond to the ceramic
1960
1970
1980
1990
2000
2010

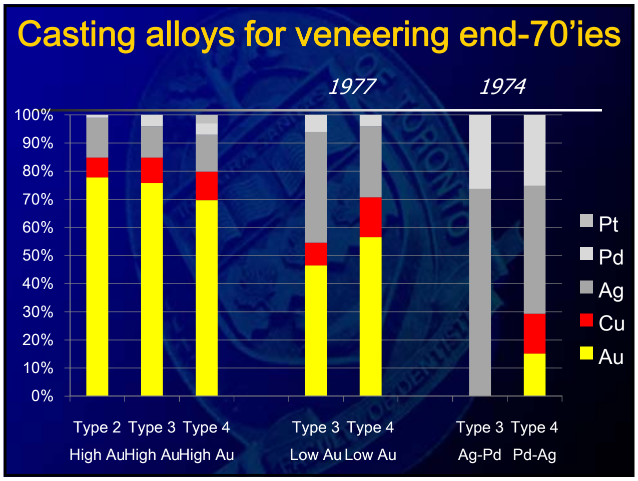

Ceramic veneering of casting alloys
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Au/Pd/Pt
•Casting Temp 1260°C → prone to temperature distortion ("Sag") when sintering the ceramic
•Hardness relative low
•Yield strength relative low
•Stiffness relative low
•Ductility relative low
•Density 18-19 → "heavy"
•Not full ceramic coverage if >3 units
•Facial ceramic veneer (only)
Ag
Pt
Pd
Au

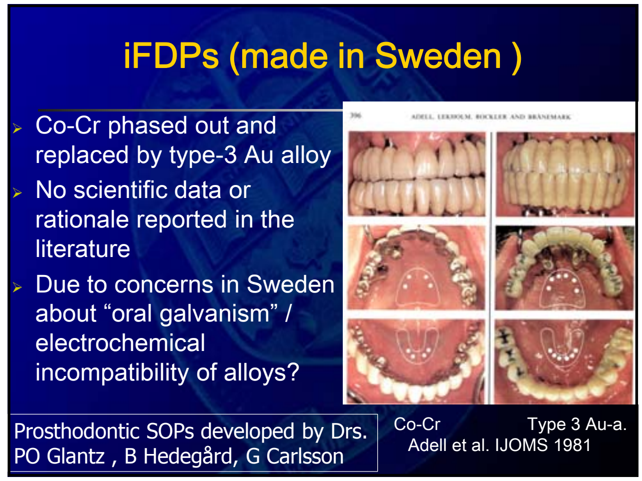

Casting alloys for veneering
Au-alloy (Acrylic)
1956: Au-Pt-Pd
Cast Co-Cr-(Acrylic)
~1965→ Brånemark research group
OSSEOINTEGRATED IMPLANTS
in the Treatment of the Edentulous Jaw
1960
1970
1980
1990
2000
2010

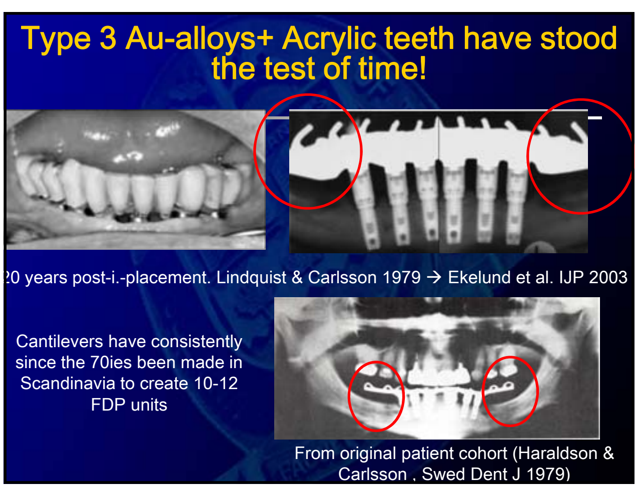

~1965→ Brånemark research group
"High core strength while facilitating anticipated modifications of the supra-structure during the implant technology development"
Fig. 21. Three bridge designs used in the methodological development. A) Design at abutments. B) Design at pontics. I and II were used during the initial and development project periods. I) Thin chrome-cobalt-molybdenum bar soldered to abutment attachment cylinders with acrylic teeth in an acrylic base. II) is constructed mainly as I), but with a more sturdy bar. III) Conventional bridge design consisting of a gold base with acrylic or porcelain facings.
36
1971
1977

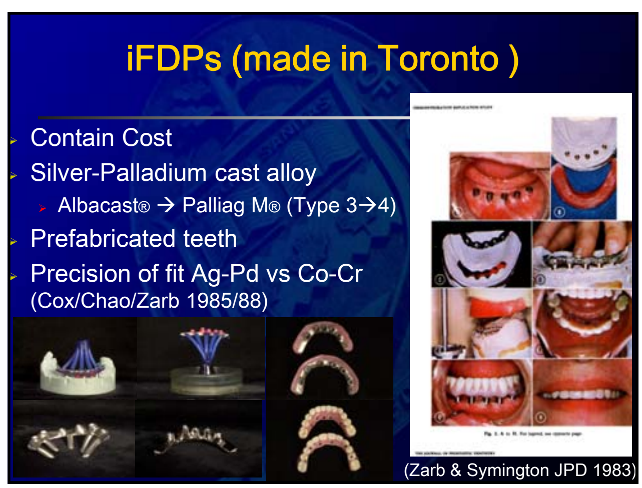

Costs of precious metals, mid-70'ies
US$
300
250
200
150
100
50
0
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
!
AU
PT
PD
http://www.goldmastersusa.com

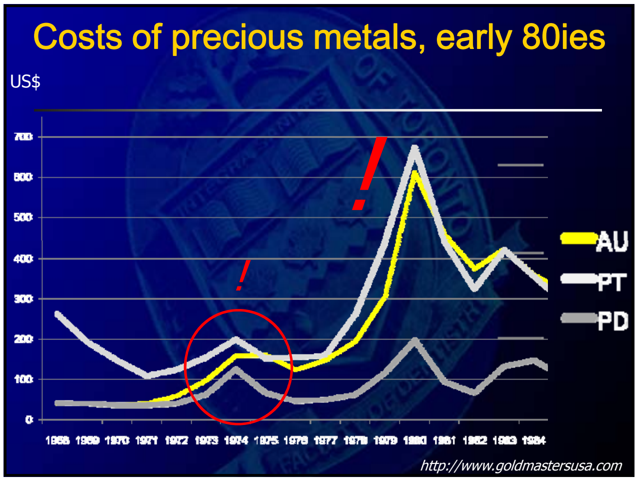

Casting alloys for veneering end-70'ies
Au-alloy (Acrylic)
Au-Pt-Pd
1977: Au-Pd
1974: Pd–Ag/Ag-Pd
Cast Cobalt-Chromium-(Acrylic)
Requirements of alloys for dental restorations
Castability
Ease of finishing and polishing
Corrosion resistance
Rigidity
Compatibility with veneering material
Cost
1960
1970
1980
1990
2000
2010

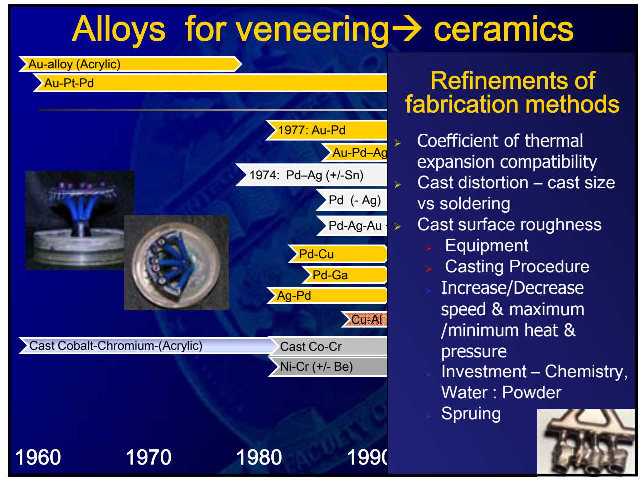

Casting alloys for veneering end-70'ies
1977
1974
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pt
Pd
Ag
Cu
Au
Type 2 Type 3 Type 4
High Au High Au High Au
Type 3 Type 4
Low Au Low Au
Type 3 Type 4
Ag-Pd Pd-Ag

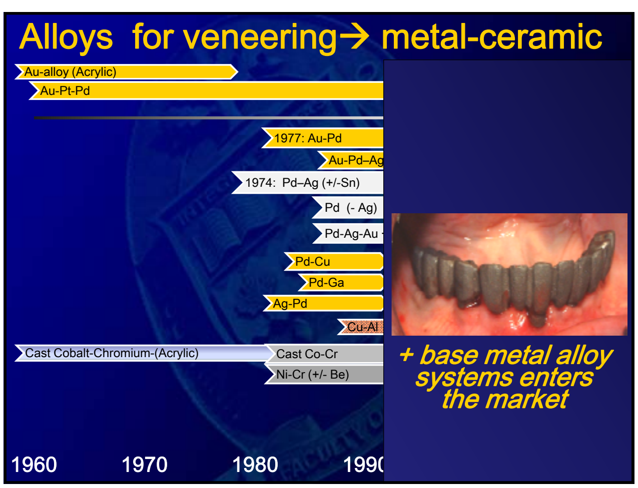

iFDPs (made in Sweden)
Co-Cr phased out and replaced by type-3 Au alloy
No scientific data or rationale reported in the literature
Due to concerns in Sweden about "oral galvanism" / electrochemical incompatibility of alloys?
Prosthodontic SOPs developed by Drs. PO Glantz , B Hedegård, G Carlsson
Co-Cr
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)


Costs of precious metals, early 80ies
US$
700
600
500
400
300
200
100
0
1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984
AU
PT
PD
!
!
http://www.goldmastersusa.com


Alloys for veneering→ ceramics
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)
1960
1970
1980
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
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)
+ base metal alloy systems enters the market
1960
1970
1980


Cobalt-Chrome – Ceramic
From: Kourkouta et al. Br Dent . 2007

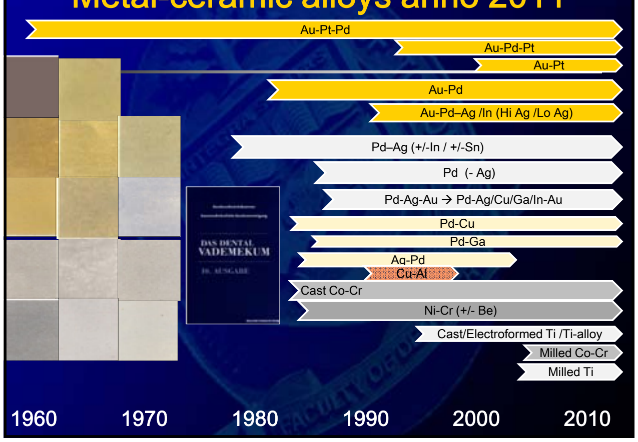
Base vs Noble metal casting alloys

- 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

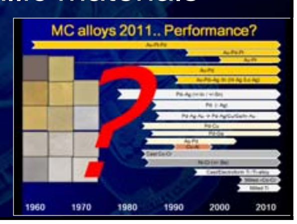
Costs of precious metals, 2011

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?

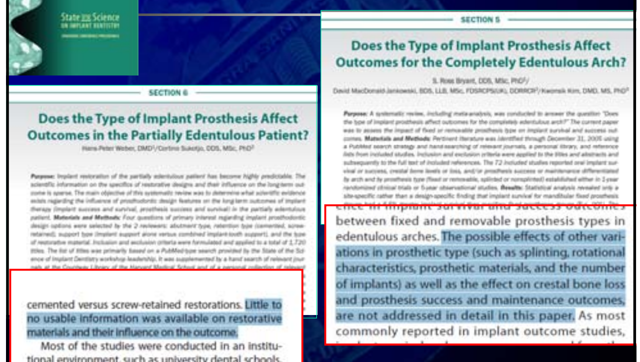


Recent Systematic Reviews, Clinical performance of FDPs

- 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

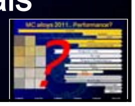
None of these identified failures/outcomes in terms of alloy composition

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



Quest for information:

1. Which 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 ?



The optimal design for an FDP?

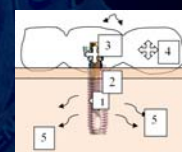
Excellent marginal fit
Withstand occlusal forces
Minimal biofilm formation
Access for oral hygiene
Satisfactory aesthetics

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

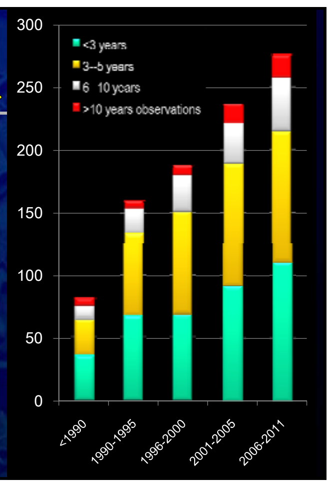
Further research for optimizing design of implant-retained FDPs?

- 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

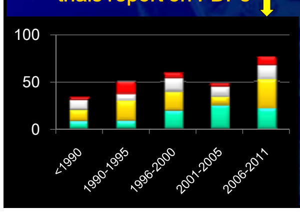


- Hardly any biomechanical theories have been confirmed by clinical outcomes (Bryant et al. 2007).

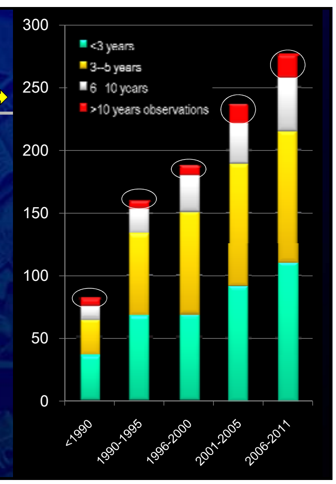
Clinical studies of prostheses retained by implants: n=738/3005 trials report on FDPs



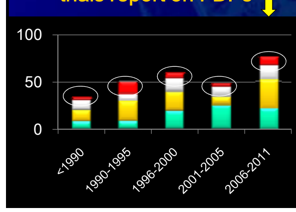
Clinical studies of prostheses retained by teeth: n=228 /502 trials report on FDPs



Clinical studies of prostheses retained by implants. n=738/3005 trials report on FDPs)



Clinical studies of prostheses retained by teeth. n=228 /502 trials report on FDPs



FDPs Retained by implants

Clinical study reports (n = 738)

Observation period < 10 years (n = 685)

Observations =>10 years (n = 53)

FDP alloy not described (n = 23)

Alloy described (n = 30)

FDPs Retained by teeth

Clinical study reports (n = 228)

Observation period < 10 years (n = 190)

Observations =>10 years (n = 38)

FDP alloy not described (n = 18)

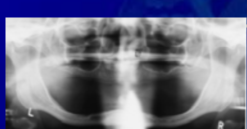
Alloy described (n = 20)

AgPd: Albacast/PalliagM: Attard/Bryant/Wyatt /Zarb 1998-04 a,b,c,d,e,f,g,h,I,j,k l **Type3Au:** Lindquist /Carlsson /Jemt /Ekelund 1994-03 a,b,c,d,e,f Åstrand ea. 2008 **“Gold alloy”:** Gunne ea 1999 **“Gold or Co-Cr”**: Brånemark /Adell /Jemt/Ivanoff 1977-2000 a,b,c,d **Cp1/Cp2 Ti & "cast gold “**: Örtorp & Jemt 2006-09 a,b,c,d, "**precious alloy" / "cast gold“**: Eliasson ea 2006 **"precious/semi-precious alloy** : Lekholm ea 1999	**Type4Au: Degudent U**: DeBacker ea, 2006-08a,b,c,d,e,f **Type3Au: KAR Gamma:** Valderhaug ea 1980-97a,b,c,d **Type 3Au: Sjöding:** Karlsson ea 1989 **Au-Pd/ Ni-Cr (several)**: Anderson / Vet.Adm. 1993 **“Co-Cr”:** Öwall ea, 1991 **“Gold”**: Lindhe & Nyman 1984 Glantz ea 1993 Yi ea 1996&97 Hämmerle ea 2000 **“High noble”:** Walton 1997 **“Precious alloy”:** Sundh & Ödman 1997

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

1. vertical space
2. cantilevers

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



“…*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

Zarb et al. 1983: *“ edentulous for at least 5 years*”
Quirynen/Naert/vanSteenberghe 1982-89: *“period of edentulousnes 0-25 yrs”*
Meijer/Visser/Raghoebar 1998: *“mean edentulous period 21yrs”*

The average edentulous patient 1980

Vertical space increases with period of edentulousnes

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

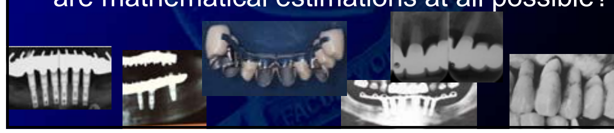
For free, harmonic vibrations the Timoshenko-Rayleigh equations take the form

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

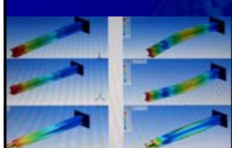
From: wikipedia.org

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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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
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

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
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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Thank you for your kind attention