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

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Long-term clinical studies

Practice-Based-Research-Network Clinical Trials

Cl. II amalgams 10 years

Cl. II glass-ionomers 5 years
Mjor & Jokstad. J Dent 1993

Cl. III/IV composite resins 10 years

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

Study 1: RCT, 10+ years

Study 2: Prospective cohort 25+ years

Assessment of the peralpal and clinical status of crowned teeth over 25 years

J. Valderhaug, A. Jokstad, F. Antigensim and P. W. Scherry
Department of Prosthodontics and Biomaterials, University of Oslo, Oslo, Norway

Abstract
The purpose of this study was to examine microscopically changes in the proximal teeth and crowns of 41 crowned teeth placed by crown and a control group of 21 non-crowned teeth placed by crown for 25 years. The teeth were examined using a stereomicroscope at the end of the study, and the results were compared with those of the control group. The results showed that the crowned teeth were in better condition than the control group, with less wear and tear on the crown surfaces. The study concluded that crowned teeth are more durable and wear-resistant than non-crowned teeth, and that the use of crowned teeth is recommended for long-term clinical use.
Study 3: Retrospective Cohort study, 10-20+ years

### Placed Material combination %

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Jokstad &amp; Mjor J Dent 1996 1983-85 61p→40p</td>
<td>&quot;Metal-Ceramic&quot; or &quot;Gold-Acrylic&quot; casting alloy 5% after 10 yrs None. 31/135 retainers failed (predominant caries)</td>
<td></td>
</tr>
<tr>
<td>Teigen &amp; Jokstad COIR 2011 1987-95 198p</td>
<td>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 &gt;0.4/yr (n=41): Co-Cr-cer: 8% Co-Cr-Acryl: 35%</td>
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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?
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?

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

<table>
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<tr>
<th>TYPE</th>
<th>HARDNESS</th>
<th>USE</th>
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<tbody>
<tr>
<td>I</td>
<td>SOFT</td>
<td>Single surface restoration</td>
</tr>
<tr>
<td>II</td>
<td>MEDIUM</td>
<td>Inlays, onlays</td>
</tr>
<tr>
<td>III</td>
<td>HARD</td>
<td>Onlays, crowns, Short span FDPs</td>
</tr>
<tr>
<td>IV</td>
<td>EXTRA</td>
<td>Post/cores; Long span FDPs, RPDs</td>
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|------|------|------|------|------|------|------|
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

Ceramic veneering of casting alloys

- 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

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)
Casting alloys for veneering

~1965 → Brånemark research group

Requirements of alloys for dental restorations
- Castability
- Ease of finishing and polishing
- Corrosion resistance
- Rigidity
- Compatibility with veneering material
- Cost

Costs of precious metals, mid-70'ies

http://www.goldmastersusa.com
Casting alloys for veneering end-70’ies

- Pt
- Pd
- Ag
- Cu
- Au

Type 2 Type 3 Type 4
High Au High Au High Au
Low Au Low Au
Ag-Pd Pd-Ag

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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?

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

- 10 years post-placement. Lindquist & Carlsson 1979 → Exelund 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)

(iFDPs made in Toronto)

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

Co-Cr Preferred Type 3 Au-a.
Adell et al. IJOMS 1981

From original patient cohort (Haraldson & Carlsson, Swed Dent J 1979)
Alloys for veneering → ceramics

- 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

+ base metal alloy systems enters the market

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

**Metal-ceramic alloys anno 2011**

- Au-Pt-Pd
- Au-Pd-Pt
- Au-Pd
- Au-Pt
- Pd–Ag (+/-In / +/-Sn)
- Pt-Ag-Au → Pt-Ag/Cu/Galn-Au
- Pt-Cu
- Pt-Ga
- Ag-Pt
- Ni-Cr (+/-Be)
- Cast Co-Cr
- Ni-Cr (Ni-Bed)
- Cast/Stainless Steel (Co-Cr)
- Milled Co-Cr
- Milled Ti.

**Costs of precious metals, 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
- Sailer ea. (Implant) COIR 2007
- Goodacre ea. (Teeth/Implant) JPD 2003a,b

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

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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).

**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
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.

Many of our edentulous patients today are not similar anatomically to the average patients treated in 1980.
Some supra-structures require much vertical space due to bulk

"Toronto-bridges"

Cantilever risk confusion - SRs published in 2009:

1. Aglietta et al., Clin Oral Implants Res 2009: "ICFPs 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:

\[ D = \frac{F}{E} \left( \frac{L}{W \cdot H} \right) \]

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

From: wikipedia.org

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?

Stress and deformation of the supra-construction with cantilevers

Cantilevers - theory and practice?

(n=11, 1-20+ yrs)
- Co-Cr + acrylic teeth
Placement 1968
3/11 framework fractures

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
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.

Thank you for your kind attention.