Four year follow-up of fixed partial dentures in cobalt-chromium with porcelain veneers

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Abstract

**Purpose:** The aim of this retrospective study was to evaluate the clinical performance of metal-ceramic fixed partial dentures (FPDs) and single crowns made in cobalt-chromium with porcelain veneers. **Materials and methods:** The material comprised a total of 41 patients (16 women and 25 men) with a mean age of 63 years (range 40-89) generally having severely compromised dentitions. They received a total of 50 FPDs with a mean of 9.5 units (range 3-14) and 12 single crowns. Of the FPDs, 31 were provided with one or more extension units on one (n=23) or both sides (n=8). The mean observation time was 51 months (range 28-80). Complications of the FPDs were registered and two independent examiners performed an assessment according to the CDA evaluation system. **Results:** Seventeen (34%) of the FPDs had one or more biological or technical complications. Six (12%) FPDs were totally or partially removed during the observation period. The fit of the abutment crowns were in more than 98% rated as excellent according to CDA. **Conclusion:** This study shows that the long-term outcome of metal-ceramic FPDs made in cobalt-chromium alloy compare quite favorably to FPDs made in titanium or gold alloys.

**Keywords:** Cobalt-chromium alloys; dental porcelain; dental prosthesis failure; fixed partial denture; follow-up studies
Introduction

The use of fixed partial dentures (FPDs) for replacing lost or missing teeth has been a standard procedure for many years. The metal framework was originally made in a gold alloy, and tooth colored veneers were used in the esthetic zone of the dental arches. Different materials have been utilized for veneering the metal framework, and in the past the most used veneer materials were acrylic resins or porcelain cemented to the metal framework. In the late 1950s, new gold alloys were developed with thermal expansion properties similar to that of dental ceramics, making the metal-ceramic crown a reality (Phillips 1982). During the first decade after the invention, the majority of metal-ceramic crowns and FPDs were constructed with the use of noble alloys, and this treatment modality has now been in use for more than four decades.

With the deregulation of the gold price in 1969, it has continued to increase over the years. In order to decrease the cost of metal-ceramic treatment, other porcelain-compatible metal alloys were developed; e.g. silver-palladium (Ag-Pd) and base-metal alloys. However, cost-benefit has been minimized by the prize increase of gold substitutes, e.g. alloys containing palladium. For many patients the cost for dental treatment is of great importance and the pursuit of less expensive materials has been one of the
incitements for developing new alloys suitable for metal-ceramic prostheses.

A higher modulus of elasticity is another reason for using other alloys than gold, which to greater extent prevents the problem of dimension in large FPD constructions. If bending forces are present, they will result in chipping or cracking of the porcelain if the metal framework is not strong enough. Therefore, in FPDs with cantilevers, or in extensive constructions with only few abutments, there is a need for a strong material that withstands such unfavorable loads. In this regard, most base-metal alloys have this property and present a modulus of elasticity that is twice as high as that of gold alloys (Moffa 1983, Brown and Curtis 1991, Wataha 2002).

Today, there is a large variety of alloys available from different manufactures, ranging from high-precious alloys to pure base-metal alloys. The number of alloys for fixed prosthetic restorations has increased over the last decades and there are now several hundred commercial brands of alloys available for FPDs. The use of alternative alloys such as base-metal alloys and titanium have increased during the last decades worldwide. For resin-bonded FPDs, many dentists and dental technicians prefer to use base-metal alloys due to the increased possibility to create a less bulky framework which, in turn, is dependant on their superior physical properties compared to gold alloys. The failures usually reported on bonded FPDs are loss of retention, but technical complications of the metal framework or the veneers

When base-metal alloys were introduced for full coverage crowns, one of the shortcomings was the difficulty of casting the crown with a good marginal fit. There are several studies on the castability of the first generation of base-metal alloys and most of them concern nickel-chromium (Ni-Cr) alloys. The results were, however, not satisfactory for many of the tested alloys (Hansson 1985, Johnson 1983). In one study that compared different alloys, FPDs made in non-precious alloys had a significantly larger marginal gap than those made from high-precious alloys. However, there was no significant difference between the Ni-Cr alloy group and the Ag-Pd alloy group. In the discussion, they concluded that some of the constructions would have shown a better marginal fit if they had been sectioned and soldered (Northeast et al. 1992).

Different studies report diverging results depending on the materials and methods used for measuring the castability. In some studies, the nickel-chromium-beryllium (Ni-Cr-Be) alloys are found to be superior compared to other base-metal alloys and high-noble alloys (Baran 1985, O’Connor et al. 1996). In clinical studies, different Ni-Cr alloys were tested with a conventional gold alloy as control. In those studies, one of the base-metal alloys was comparable to the gold alloy, and Ni-Cr alloy without Be gave inferior results (Moffa et al. 1984, Anderson et al. 1993).
During the last two decades there has been a continuous development of new alloys in order to overcome the problems with casting and fusing compatibility to dental porcelain. The early problem with casting a restoration in base-metal alloy with an acceptable marginal fit has today been solved with new alloys and better casting techniques. (O’Connor et al. 1996, Oruç et al. 2000).

The choice of base-metal alloy for prosthetic constructions differs over the world. In the United States, Ni-Cr alloys are frequently used which is in contrast to Europe and Japan where most base-metal alloys used for FPDs are based on Co-Cr. Those containing more than 1% nickel are generally not utilized at all. Ni-Cr alloys are easier to cast and less expensive than Co-Cr alloys but their physical properties and their corrosion resistance are not as good. When an alloy is exposed to heat treatment, such as in porcelain firing, its physical properties might change and the alloy becomes weaker making it less suitable for long span FPDs. In this respect, Co-Cr alloys are superior to Ni-Cr alloys in regard to their ability to withstand heat treatment (Morris 1990, Sing et al. 1999).

In dentistry, alloys based on Co-Cr have been used for removable partial dentures (RPDs) since 1929. Based on the successful dental application of Co-Cr appliances, they have been further developed in the medical field and are utilized for numerous orthopedic devices, amongst others (Tesk 1986).
Although casting of a non-precious alloy now is possible to perform with an acceptable fit, it is more time consuming than casting of high-precious alloys. Therefore, the cost benefit from using a less expensive alloy material is reduced. Another problem, which had to be solved with base-metal alloys, was the difficulty in soldering. Early studies of soldered base-metal alloys showed less promising results with poor flexural strength and porosities in the surface of the joint. Up to 35% of dental laboratories reported problems in soldering base-metal alloys (Moffa 1983). In comparison between different base metal alloys, more recent studies reported more favorable results and Co-Cr alloys presented stronger soldered connections than Ni-Cr (Gustavsen et al. 1989, Lima Verde and Stein 1994, Harikesh et al. 2000).

With the introduction of laser-welding, the problem of soldering base-metal alloys was to some extent solved, but the laser-welding machine is expensive which prevents a more widespread use. Some studies performed on laser-welding of base-metal alloy and titanium show that the welded joint is stronger than soldered joints and almost as strong as the un-welded test sample (Aphotheker et al. 1984, Bertrand et al. 2001, Liu. et al 2001, Baba et al. 2004).

Research during the last 10-15 years has resulted in the development of new base-metal alloys with good castability and a thermal expansion similar to that of noble gold alloys. Early studies on the strength of the porcelain bond of different base-metal alloys compared to high-noble alloys, reported lower
bond strength and more adhesive fractures with the former (Daftary et al. 1986, Uusalo et al. 1987). To use conventional veneering-porcelains employed in high-noble alloys, could be an advantage since their technical management is well known to dental technicians and ordinary laboratory equipment can be utilized. The conventional technique and application of veneering porcelains on high-precious alloys are well documented in several studies. In this regard, follow-up studies on metal-ceramic FPDs casted in high gold alloys have reported good long-term results (Walter et al. 1999, Näpänkangas 2002, Walton 2002).

Although the fusing of porcelain to base-metal alloy is more technique-sensitive compared to fusing to noble alloy, laboratory tests have shown that porcelain bonding strength to base-metal alloy may be as good or even better than the bonding strength to noble alloys (Barghi et al. 1987). A good bond between Co-Cr alloy and porcelain can be achieved without a bonding agent (Wu 1991) as is necessary with Ni-Cr. In addition, the higher melting temperature of base-metal alloys is an advantage compared to noble alloys and reduces the risk of distortion and sagging during the porcelain firing.

When an alloy is inserted in the oral cavity it will be exposed to different solutions (saliva, drinks, food etc.) and thus tends to corrode. The precious alloys owe their oral biocompatibility to their resistance to oxidation and corrosion. The non-precious alloys owe their biocompatibility to corrosion resistant oxide layers (Marek 1985). As regards the latter alloys, it has been
speculated that abrasion, polishing, wear and high local acidity or high chloride content may break up the oxide film resulting in the release of metal ions together with traces from the oxidation layers (Wataha et al. 1998, Wataha et al 1999, Wataha 2000, Hensten-Pettersen 2000). The ion release could be of significance for the dental technicians who inhale dust during grinding and polishing, especially important for alloys containing beryllium and nickel, and therefore the handling of base metal alloys could be an occupational health hazard (Moffà 1983, Johnson 1983, Baran 1985). Most studies concerning corrosion of non-precious alloys are carried out on Ni-Cr alloys, others are done on Co-Cr alloys or both types. The conclusion has been drawn that Co-Cr alloys are more resistant to corrosion than Ni-Cr alloys (Marek 1985, Mülders et al. 1996, Wataha 2002). Although most laboratory studies have shown that noble alloys are more biocompatible than non-precious alloys (Wataha 1999, Wataha 2000, Al-Hiyasat et al. 2002), the clinical implications of these results have not yet been established. The incidence of side effects in prosthodontics is low and adverse reactions are reported for both gold and base-metal alloys (Hensten-Pettersen 1992, Mjör et al. 1993, Hensten-Pettersen et al. 2000). As mentioned previously, Co-Cr alloys have been used for RPDs for more than 70 years with predictable positive long-term results and very few reports of adverse effects have appeared in the literature. Clinical studies on the release of metal ions from RPD frameworks shows that the Co release is
probably of a magnitude that is unlikely to make an obvious contribution to the daily intake of Co in man (Stenberg 1982). The use of a Co-Cr framework for FPDs, where most of the framework is veneered with dental ceramics, reduces further the exposed alloy surface. Thus, in FPDs cast in base-metal alloy, the release of metal ions from the framework is probably small, and, as its surface generally is almost completely covered with the porcelain veneer, it is unlikely that the use of base-metal alloys results in toxic reactions (Tesk 1986, Mjör and Christensen 1993).

Follow-up studies of metal-ceramic FPDs made in these new base-metal alloys are few, and no long-term data concerning the longevity and biocompatibility are available. Since the use of base-metal alloys for FPDs is increasing, there is a need for clinical evaluations of these alloys.

The aim of this retrospective study was to evaluate the clinical performance of FPDs and single crowns made in Co-Cr with porcelain veneers and to analyze the relationship, if any, with registered clinical parameters. The hypothesis is that FPDs in Co-Cr will compare favorably to results reported on metal-ceramic FPDs made in titanium and high-precious gold alloys with regard to longevity, technical and biological complications.
Material and Methods

Type of study

The study was performed as a retrospective study, using data collected from dental records, radiographs and the patients were requested to attend a clinical investigation. The clinical investigation comprised radiographs, periodontal and endodontic assessment of the abutments and an evaluation of the FPDs using the California Dental Association (CDA) system for quality assessment of dental care (California Dental Association 1977) by two independent calibrated specialists in Prosthodontics.

Search strategy

Books available at the library of Postgraduate Dental Center in Örebro were screened for relevant information on the subject, and a Medline search was conducted (Pub Med at www.ncbi.nlm.nih.gov). The following search terms, alone or in combinations, were used: “fixed partial dentures”, “fixed prosthodontics”, “dental alloy”, “metal-ceramics”, “follow-up studies”, “cobalt-chromium alloy”, “corrosion”. The titles and abstracts were screened for possible relevance for this study and subsequently ordered in full text.

Patient selection

Ethical approval was obtained for the study and all participants signed an informed letter of consent. The inclusion criteria comprised:
• All patients treated with metal-ceramics FPDs (≥ 4 units) and/or single crowns with metal framework in Co-Cr alloy performed by the author during the period January 1997 to December 2000.

• A minimum of three years of service of the prostheses was required so that wear and/or degradation of the veneering porcelain and technical complications would have had time to appear.

There were no exclusion criteria, and patients, for example with history of heavy bruxism, drug abuse, or compromised teeth were included. (One of the reasons for choosing this treatment was a dubious long-term prognosis for the remaining teeth).

The clinical examination was performed during the period November 2003 to February 2004. There were a total of 44 patients treated with metal-ceramics FPDs and/or single crowns fabricated in Co-Cr alloy. Of these, 41 (25 men and 16 women) accepted to participate in the study. As regards the dropouts, 1 patient did not want to participate in the study and 2 patients could not be reached by mail or telephone.

The 41 patients had received a total of 50 FPDs and 12 single crowns. Frequency distribution of gender, jaw and type of extension on the FPDs are shown in Table 1. Some patients were treated in both jaws, either with a FPD in one jaw and single crowns in the opposing or with FPDs in both.
Table 1. Number of FPDs according to gender, jaw and type of extension

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maxilla</td>
<td>Mandible</td>
<td>Maxilla</td>
<td>Mandible</td>
<td></td>
</tr>
<tr>
<td>No extension</td>
<td>10</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Unilateral extension</td>
<td>7</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Bilateral extension</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>13</td>
<td>11</td>
<td>6</td>
<td>50</td>
</tr>
</tbody>
</table>

Fig 1 A. Dubious prognosis

Fig 1 B. Dubious prognosis

Fig 2 A. Periodontally compromised

Fig 2 B. Periodontally compromised

Fig 3 A. Economic reason

Fig 3 B. Economic reason
The patients treated with this type of restorations could roughly be attributed to any of the three following categories:

- Patients with few remaining teeth where the prognosis for a FPD was judged to be dubious (n = 10) (Figs 1 A and B).
- Patients with periodontally compromised teeth (n = 18) (Figs 2 A and B).
- Patients with a high treatment need for prosthetic restorations but having a poor economic situation (n = 13) (Fig 3 A and B).

**Clinical procedure**

The prosthetic treatments, all carried out by the author, were performed according to the following standardized protocol:

- The abutment teeth or artificial core were prepared with a shallow chamfer or featheredge preparation with a height of at least 4 mm and an as parallel-sided as possible.
- In endodontically treated teeth with posts and cores, it was ensured that the finish line encompassed a cervical circumferential ferrule of at least 2 mm of the root surface below the artificial core.
- The metal framework was tried in separately, and in cases of misfit the framework was sectioned and laser-welded and tried in again before porcelain application.
- The FPDs were adjusted to a stable occlusion in intercuspal and retruded contact position, free of interferences in horizontal
movements, and if possible anterior guidance was established in lateral
and protrusive movements.

- The constructions were fabricated from Wirobond C (Bego Bremer
  Goldschlägerei, Bremen, Germany) and Vita 900 (Vita Zahnfabrik, Bad
  Säckingen, Germany) by a local dental laboratory.

All patients were offered yearly check-ups after receiving the prosthetic
treatment and the majority, but not all, attended the recalls.

**Clinical examination**

The clinical examination was, if possible, performed by a prosthodontist
who had not been involved in any previous treatment of the patient.
Radiographic examination included intraoral radiographs using parallel
technique for all but one patient where the panorama technique was applied.
The CDA evaluation was done by two prosthodontists independently and if
the registrations differed, agreement was reached after mutual
reexamination of the patient and a discussion between the two examiners.

**Registered variables**

On the individual level, age, gender, jaw, number of crowns and FPDs were
registered. On the construction level, number of units, abutments, pontics,
extension units and endodontically treated teeth were registered per FPD.
Technical complications and corrective procedures were collected from the
patient records and from the interview at the clinical examination. Types of
complications such as fracture of veneer or framework, loss of retention or
abutment, caries, tooth-fracture, endodontic or periodontal complications were recorded. Any correction or complete or partial removal/remake of the construction was registered.

After the clinical examination the CDA evaluation system was used for quality assessment. The CDA system is based on two main categories, “satisfactory” and “not acceptable” with two sub-ratings within each category. The following parameters were registered.

- Surface and color
- Anatomic shape
- Marginal integrity

Statistical methods

All data was analyzed in Statistical Package for Social Sciences (SPSS) version 12 (SPSS Inc. Headquarters, Chicago, Illinois, USA). A Mann Whitney U-test was used in order to detect any differences between presence of complications and clinical variables, and a Kruskal Wallis test to evaluate any relationship between complications and treatment group.
Results

Of the 50 FPDs, 44 comprised 7 units or more within a range of 7 to 14 units. The average FPD had 9.5 units on 5.6 abutments (Table 2). Thirty-one of the FPDs had cantilevers of which 12 had 2 cantilevers uni- or bilaterally and 19 had not more than 1 cantilever on one or both sides. Of the 281 abutments, 189 (67%) were vital at cementation, and, at the follow-up, 11 (6%) of the initially vital abutments were endodontically treated, in need of endodontic treatment or were extracted. Of the 92 endodontically treated teeth (at baseline) 14 (15%) had at the follow-up undergone apical surgery, were in need of endodontic retreatment, or were extracted.

Table 2. Number of units, abutments, pontics, endodontically treated abutments and post and cores per construction and per single crown (Si) at the follow-up.

<table>
<thead>
<tr>
<th>Number of units</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructions</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>18</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Abutments</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5-6</td>
<td>5-7</td>
<td>5-8</td>
<td>6-8</td>
<td>8</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Pontics</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3-4</td>
<td>3-5</td>
<td>2-5</td>
<td>4-7</td>
<td>2-7</td>
<td>5-7</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Endo treated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0-2</td>
<td>0</td>
<td>3-6</td>
<td>0-6</td>
<td>0-6</td>
<td>0-2</td>
<td>2-7</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Post and core</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0-2</td>
<td>0</td>
<td>1-6</td>
<td>0-6</td>
<td>0-6</td>
<td>0</td>
<td>2-7</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

As regards the single crowns, none were lost, had endodontic complications or showed any chipping of the porcelain. Among FPDs, 2 were lost, another 4 were partly removed, and a 10-unit FPD with bilateral double-cantilever
extension units fractured in a welded joint in the midline after 40 months. This construction had been separated and laser-welded due to misfit at the initial try-in of the metal framework. Of the 4 partly removed FPDs, 3 had been partly removed due to loss of distal abutment on one side for periodontal or endodontic reasons. One of the partly removed FPDs, a 10-unit FPD came loose at the distal abutments on both sides, together with the old posts and cores. The loose sections were removed and the extension cantilever units were cut off before the crowns were recemented.

Table 3. Distribution of FPDs with and without complications and type of complication by treatment group at the follow-up (some FPDs presented more than one complication).

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Periodontal indication</th>
<th>Dubious prognosis</th>
<th>Economic reason</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No complication</td>
<td>17</td>
<td>7</td>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>Complication</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of complication</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of retention</td>
<td>4</td>
</tr>
<tr>
<td>Framework fracture</td>
<td>1</td>
</tr>
<tr>
<td>Major porcelain fracture</td>
<td>1</td>
</tr>
<tr>
<td>Minor porcelain fracture</td>
<td>8</td>
</tr>
<tr>
<td>Endodontic complication</td>
<td>3</td>
</tr>
<tr>
<td>Periodontal complication</td>
<td>2</td>
</tr>
<tr>
<td>Root fracture</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
</tr>
</tbody>
</table>
Table 3 shows the number of FPDs with or without complications and the different complications registered during the follow-up period. Individuals who had some type of complication had a significantly higher number of abutment and pontics in the constructions compared to those who had not exhibited any complications (P<0.05). As regards to porcelain fractures, individuals who received the construction for economic reasons had significantly more veneer fractures than patients in the other treatment groups “dubious prognosis” and “periodontally compromised” teeth (P<0.05).

CDA evaluation

The CDA evaluation of the FPD units was made in three different categories: surface and color, anatomic shape and marginal integrity. Each unit was given a final rating based on the lowest rating in any of these three categories. The majority of FPD units evaluated had a final rating of satisfactory, most of them were given the rating Sierra with a few units (14.5%) rated Romeo. The percentage distribution of units according to the CDA rating system per category is shown in Table 4. The major reason for a final rating of Sierra for the unit was that most units had visible signs of wear of the porcelain veneer noticeable as a polished flattened surface, or a slightly rough surface, and, in a few cases, chipping of the veneer. In FPD units with fractures of the veneering porcelain, most fractures were small, and only 2 units presented fractures through the opaque layer. There was a
total of 21 (4.7%) units with porcelain fractures of which three individuals in the “economically strained group” accounted for 16 units.

Table 4. Percentage distribution of 443 units with respect to evaluation in accordance to the CDA system at the follow-up.

<table>
<thead>
<tr>
<th></th>
<th>Satisfactory</th>
<th>Not acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Romeo</td>
<td>Sierra</td>
</tr>
<tr>
<td>Surface and color</td>
<td>16.5</td>
<td>83.3</td>
</tr>
<tr>
<td>Anatomic shape</td>
<td>80.8</td>
<td>18.7</td>
</tr>
<tr>
<td>Marginal integrity</td>
<td>98.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Final</td>
<td>14.5</td>
<td>84</td>
</tr>
</tbody>
</table>

There was a difference in the rating of anatomic shape between the pontics and the abutments where 30% of the abutments were given the rating Sierra due to a slightly over-contoured crown, whereas 90% of the pontics were rated Romeo. Almost all abutments and single crowns were given the rating Romeo for their marginal integrity; only 3 abutments were given the rating Victor due to root fractures and secondary caries. Interexaminer concordance (percentage agreement) for the CDA evaluation was 88% for “surface and color”, 99% for “marginal integrity” and 79% for “anatomic shape”. The periodontal situation were, for most of the abutments, stable during the follow-up with little or no changes, but 2.5% of the abutments presented bone-loss of 2 mm according to the radiographic evaluation at the follow-up compared to baseline. There were no adverse reactions towards the metal-ceramic crowns or FPDs reported by the patients.
Discussion

The absence of a control group in the present study requires some elaboration. Ideally, a control group comprising matched cases treated with metal ceramic FPDs in high-precious gold alloy (the so-called “golden standard”) should have been included. The patients in this study had dentitions with periodontally compromised teeth, as well as weak and unevenly distributed abutments, and in some cases, the patients had a strained economic situation. Considering the higher cost for FPDs made in precious gold alloy, and depending on the patient selection, the calculated risk for failure was high. Therefore, it would not have been ethical to treat this category of patients with FPDs in precious gold alloy. In order to compensate for the lack of a control group, other comparable studies (as regards follow-up time, CDA evaluation etc.) were used in the evaluation and interpretation of the results.

In Scandinavia, most metal-ceramic crowns and FPDs are made in gold-alloys, but the use of alternative materials is increasing, titanium and Co-Cr alloys being the most popular of gold substitutes. In this study many of the patients had a dubious prognosis for the remaining teeth supporting the FPDs, and that was generally the reason for using an alternative alloy. In the group of patients with periodontally compromised teeth, there were individuals who had received periodontal treatment for many years but still
had a continuous breakdown of periodontal support. For these patients the indication for providing them with FPDs were in several cases the need for splinting the remaining teeth in order to prevent increasing mobility and migration of the teeth (Nyman et al. 1975). By applying the splinting treatment regime in cases of a slowly progressing periodontitis, it may preserve the existing natural dentition for a longer period of time. In this study, these patients exhibited more frequently biological complications as well as technical complications compared to similar studies on periodontally compromised dentitions with extensive FPD treatments, where only few complications were reported (Nyman and Lindhe 1979, Laurell et al. 1991). The unstable periodontal situation in some of the patients in this study, compared to the controlled situation in the previously mentioned studies, might explain the difference in outcome.

There was a total loss of 15 (5%) of the abutment teeth, most of them being extracted as a result of periodontal complications and/or loosening of old posts and cores in the groups, “periodontally compromised teeth” and “dubious prognosis”. Two patients that lost 2 full arch FPDs together with a total of 12 abutments account for 80% of the tooth losses.

In other long-term studies of FPDs with high-precious alloys, loss of teeth has been reported in a range of 4-6% after 10 years of service (Scurria et al. 1998, Walton 2002), which compares favorably to our result of 5% teeth loss. However, the observation time is considerably shorter in this study
(x̄=4.3 years) than in the previously mentioned studies and most likely the frequency of lost teeth would be higher after another 5 years of service. On the other hand, the tooth losses in this study compares favorable to those reported on a study of telescopic crown-retained RPDs with similar patient age, abutments per construction, and follow-up time (Widbom et al. 2004).

The results in this study corresponds to a success rate of 94% on the unit level and 88% on the construction level, which could be considered relatively poor compared to, reported success rates for FPDs of 95-98% after 5 years (Glantz et al 1984, Creugers et al 1994). One could argue, however, that given the generally poor prognosis for these patients/dentitions involved in this study and the benefit for the majority of patients to keep their natural dentitions for a number of additional years, makes the result acceptable or even good.

The loosening of the constructions is not a result of the material of choice, but can probably be attributed to the status of the abutment teeth (e.g. periodontally compromised, short posts, defect cement layer in old posts) in combination with unfavorable loading conditions. Most teeth that were endodontically treated in this study were already equipped with post and core for a FPD. These posts were not remade, except in a few cases, before the making of new Co-Cr metal-ceramic FPDs. The reasons for a remake of post and core were, that either posts and cores were compromised by caries, or they were judged to be insufficient for retention of the new FPD. A more
strict assessment of the quality of the previous post and core, and a remake of the strategic posts (e.g. end abutments), may have decreased the number of abutments that became loose. One framework fracture within a patient material comprising 50 FPDs of which 44 were extensive with a mean follow-up of over 4 years compares favorably to the results in other studies (Glantz et al. 1984, Randow et al 1986, Karlsson 1989, Sciurra et al. 1998, Hämmerle et al. 2002, Walton 2002).

The number of FPDs in this study that presented veneer fractures, is somewhat higher than in other studies, but comparable to studies on metal-ceramic FPDs fabricated in titanium (Kaus et al. 1996, Walter et al. 1999, Jemt et al. 2003). The comparison does not necessarily give a fair picture depending on that the FPDs in this study were generally more extensive than in the other studies: in this study, extensive FPDs presented more complications than FPDs with fewer units. There was a statistical difference in the incidence of FPDs with fractured veneers between the different treatment-indication groups. In the group treated with FPDs for periodontal reasons, only 1 of 24 (4.2%) presented fractured veneers, while the corresponding figure in the group treated for economical reasons was 7 of 17 (41%). This indicates that unfavorable loading conditions might be different in the patient groups. Three of the patients in the “economically strained group” were responsible for 16 of the totally 21 fractured veneers
and all three of them had a pronounced tooth wear in addition to signs of bruxism before the treatment with the FPDs was initiated.

In this study, the FPDs had a mean of 9.5 units, which exceeds that found in most other studies and subsequently increase the risk for complications. The total number of units evaluated in this study was 443. Of these, 21 (4.7%) presented veneer fractures of which 19 were minor, which is similar to studies of FPDs in high-precious gold-alloys (Moffa et al. 1984, Hämmerle et al. 2000, Walton 2002, Jemt et al. 2003). The results reported for single crowns and FPDs made in titanium veneered with low-fusing porcelain, are less favorable, ranging from 6 to 40% as regards fractured or cracked porcelain veneers (Kaus 1996, Bergman 1999, Walter et al. 1999, Lövgren et al. 2000, Jemt et al. 2003).

The CDA ratings in different studies diverge, one study reporting a CDA rating of Romeo in 90% of the graded surfaces after 5 years of service, while other studies reporting less than 40% of Romeo (Bergman et al. 1999, Lövgren et al. 2000). This is in clear contrast to our findings were only 16.5% of the crowns were rated Romeo after 4 years. There can be different reasons for this difference: either the Vita 900 porcelain used in this study is softer and therefore more prone to wear than the low-fused porcelain used on the titanium crowns and FPDs, or the investigators have interpreted the CDA guidelines differently.
The CDA evaluation of anatomic shape revealed that many of the abutment teeth were slightly over-contoured which might be a result of a more feather-edged preparation of the teeth in combination with the FPDs made with fused porcelain to the crown margin on the buccal side. The marginal integrity was in most cases given the rating Romeo indicating that the fit of the constructions were rated excellent, and the intraexaminer agreement was almost 100% on this parameter.

In conclusion, in consideration to the generally severely compromised dentitions among the patients included in this study, the long-term outcome of treatment with FPDs in Co-Cr are deemed to be good. The hypothesis, that FPDs in Co-Cr will compare favorably to reported results on metal-ceramic FPDs made in titanium and high-precious gold alloys with regard to longevity, technical or biological complications, are to some extent validated and to some extent not. Additional long-term studies are needed to further test the hypothesis.
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