A 5-Year Retrospective Study of Cobalt-Chromium–Based Fixed Dental Prostheses

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Purpose: The aim of this retrospective study was to evaluate the 5-year clinical outcome for ceramic veneered cobalt-chromium (Co-Cr) fixed dental prostheses (FDPs) fitted in a private clinical setting. ***Materials and Methods:*** All patients treated consecutively with Co-Cr FDPs from January 2000 to November 2005 were included, and complications were registered. Patient records were examined for details on the restorations and abutment teeth. A total of 149 patients with 201 FDPs, 1,135 units, and 743 abutment teeth were recorded. ***Results:*** Of the 149 patients, 122 (82%) were followed for 5 years. Complications occurred in 34 patients (23%) and 38 FDPs (19%). The most frequent were caries (6.7% of patients, 5% of FDPs, 2.2% of abutments) and cement failure (6.7% of patients, 5% of FDPs, 3.1% of abutments). Cohesive ceramic fractures occurred in only 7 FDPs (3.5% of FDPs, 0.7% of units). No adhesive ceramic fractures were recorded. The 5-year cumulative rates for success and survival were 83.8% and 92.8%, respectively. ***Conclusions:*** Co-Cr FDPs appear to be a promising prosthodontic treatment modality, presenting low incidence of complications and a high survival rate during the first 5 years of function. However, long-term randomized controlled studies are necessary to confirm these findings. *Int J Prosthodont 2013;26:343–349. doi: 10.11607/ijp.3024*

Gold-based alloys have been the primary choice for metal-ceramic restorations in fixed prosthodontics for 40 years. However, the price of gold has increased, and other high noble alloys like palladium-based alloys have become more popular.[1] Base metal alloys have been used in dentistry as an alternative material for partial removable dentures since the 1930s.[1] During the 1970s, alloys with low noble content, such as nickel-chromium (Ni-Cr) and cobalt-chromium (Co-Cr), were introduced and modified for use in fixed prosthodontics.[2] However, the use of Ni-Cr alloys has been questioned because of a potential biologic response to Ni, and Co-Cr alloys are also used despite a lack of clinical tolerance studies.[3]

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In addition, several in vitro and in vivo studies have reported that Ni, Co, and Cr are released from dental base metal alloys.[4–7] Still, the long-term in vivo effects are not yet fully known.[4,8–10] The corrosion resistance of Co-Cr alloys is considered high and suitable for dental use.[11,12] In fixed prosthodontics, the material characteristics of Co-Cr are both positive and negative. The high solidus temperature makes Co-Cr suitable as a framework for ceramic veneers, and the difference from the porcelain sintering temperature minimizes the risk of framework distortion after sintering.[10] Nevertheless, the high melting temperature and thermal expansion coefficient may create problems in the laboratory since the high temperature is accompanied by an increased risk of technical difficulties.[13] The high modulus of elasticity makes it possible to design frameworks with reduced thickness and longer pontic spans compared with conventional gold alloys, but the stiffness of the material makes it more difficult to handle in terms of grinding or cutting and removing from teeth once cemented and functioning. The potential handling difficulties associated with the Co-Cr casting technique can to some extent be reduced by computer-aided design/computer-assisted manufacturing (CAD/CAM) production sequences.[14]

Increased oxidation may result in poor bond strength between metal and veneering ceramic because of chromium ion diffusion.[15,16] However, the use of a bonder may improve bond strength.[15]

Table 1 Patient Motivation for Receiving a Co-Cr FDP

Reasons for FDP (more than one is possible)	No. of FDPs
Missing teeth	88
Replacement of old prosthetics	40
Extraction due to periodontal problems	28
Extraction due to tooth/root fracture	45
Extraction due to caries	12
Caries in abutment teeth	10
Bite raising/creating more occlusion contacts*	13

*10 patients, 6 to 12 units/patient.

Table 2 Distribution of Abutment Teeth

Region	Maxilla	Mandible	Total
Incisor	120	65	185
Canine	111	78	189
Premolar	113	140	253
Molar	60	56	116
Total	404	339	743

Although Co-Cr alloys have been used as an alternative to conventional noble alloys in fixed prosthodontics,[17] there are no randomized controlled studies and only a few studies on clinical performance.[17,18] Also, no clinical studies have been published on biocompatibility when used for fixed prosthodontics. One study followed 51 Co-Cr fixed dental prostheses (FDPs) in patients with severely compromised dentitions for 3 to 7 years. Seventeen of the FDPs had biologic or technical problems, and 9 had ceramic fractures. No patients experienced adverse reactions to the material.[17] Results from another clinical study (47 months) of laser-sintered Co-Cr metal-ceramic crowns were comparable with conventionally fabricated metal-ceramic crowns.[19] Interestingly, no ceramic chipping was reported. A 5-year follow-up study on Co-Cr implant prostheses with ceramic veneering presented no significant differences compared to titanium counterparts veneered with acrylic resin teeth. However, 4 of 15 prostheses had ceramic fractures.[18]

The probably widespread use of Co-Cr and the lack of scientific documentation warrant more clinical research on both FDPs and single crowns based on Co-Cr alloys.

The aim of this retrospective study was to evaluate the 5-year clinical outcome of ceramic veneered Co-Cr FDPs inserted in a private clinical setting. The hypothesis was that Co-Cr FDPs function well in a clinical situation during a follow-up period of 5 years.

Materials and Methods

This is a 5-year retrospective evaluation of dental records of patients treated with Co-Cr FDPs (not single crowns). The treatments were performed in a private clinical setting in Sweden by two experienced clinicians (two of the authors). The FDPs were manufactured at one dental laboratory. Co-Cr was the only material used at the clinic in question at the time of the study (since 1999).

One hundred forty-nine consecutive patients received 201 Co-Cr FDPs from January 2000 to November 2005. The reasons for patients receiving FDPs are presented in Table 1. Patients were given hygiene information by a dental hygienist after cementation and were scheduled for follow-up at least once a year. There were no extra recalls for clinical examinations. Records only were reviewed and registered by two of the authors from September 2010 to February 2011. The patients were examined and data recorded by the clinician who performed the treatment during the follow-up period, and the records were reviewed later.

A number of factors such as age, sex, number of units, radiologic status, type of cement, and occluding teeth in the opposing arch were recorded. Furthermore, all complications that may have occurred were registered. Complications were biologic (caries, gingivitis/mucosal, periodontal problems, root fillings, root fractures) and technical (cohesive ceramic fractures, cementation failure). Of the patient group, 52.3% were women and the mean age at the time of cementation was 66.8 years (standard deviation: 9.4, range: 39 to 90 years).

The 201 FDPs consisted of 1,135 units (mean: 5.7 per FDP; range: 2 to 14), 743 abutments (mean: 3.7 per FDP; range: 1 to 9), and 392 pontics (mean: 1.95 per FDP; range: 1 to 6). The pontic/abutment ratio was 0.53. Of 392 pontics, 112 were cantilever pontics in 79 FDPs. Of the 112 cantilever pontics, 56 were unilateral and 56 were bilateral. Four were mesial pontics and 108 were distal. The mean pontic/abutment ratio for the cantilever FDPs was 0.57.

One hundred thirty-seven FDPs were short-span FDPs (2 to 5 units) and 64 were long-span (6 or more units). The distribution of abutment teeth is displayed in Table 2.

In the opposite arch, most patients had teeth or fixed prostheses. Only four patients had removable dental prostheses. Of the 743 abutment teeth, 221 were root filled at cementation. One hundred twenty-eight teeth had an indirect post (127 gold alloy and 1 titanium), 23 had screw posts, 17 had composite posts, and the remaining 53 were left with no post.

Success was defined as the reconstruction remaining unchanged without requiring any intervention during the observation period. With this definition, any complication during the follow-up period resulted in a failure classification.

Survival was defined as the reconstruction remaining in situ after 5 years, with or without modifications, as per Tan et al.[20] However, some modifications were considered failures: if the FDP was shortened or reduced to a single crown, if the FDP was remade due to cement failure or veneer fracture, or if the abutment teeth were extracted.

If a patient lost an FDP and received a new FDP during the follow-up period, the new FDP was not included.

The longevity of the FDPs was counted from cementation to the year of the first complication that led to a failure classification within the definition of success, and subsequently for the definition of survival. The cumulative success/survival rates (CSRs) were calculated according to actuarial life table techniques, and standard errors were calculated using the Greenwood formula.[21] The CSR values presented in this study represent events occurring from cementation day to year 5. The results can also be defined in actual outcomes, ie, the state of the patient cohort in year 5. To better describe the results and make them more comparable with other studies, Walton's definitions of outcomes[22] was also applied to the material.

These definitions are briefly described as follows:

- Successful: no evidence of retreatment other than maintenance procedures, including minor occlusal adjustments, without compromising the esthetics
- Surviving: third party examination or confirmation of no retreatment other than for successful outcome
- Unknown: patient could not be traced; surviving or successful prosthesis removed to allow for a new prosthesis
- Retreatment (repair): original marginal integrity of the retainers and teeth is maintained (endodontic therapy through retainer not considered repair)
- Retreatment (failed): part or all of retainer has been lost, modification to the marginal integrity, or a retainer has been recemented more than twice after cementation

Prosthodontic Procedures

The teeth were prepared with a deep chamfer and a convergence angle of 10 to 15 degrees, if possible. Cords (Ultrapak, Ultradent Products) were used to retract the surrounding gingiva, and electrosurgery (Elektrotom, Berchtold) was performed when necessary. Standard metal impression trays were used with hydrocolloid-alginate impression material (Image, Dux B.V; Blueprint cremix, Dentsply).

The FDPs were fabricated using the lost wax technique. The wax constructions were invested in a graphite-free phosphate-bonded investment (GC Fujivest Super, GC Europe) according to the manufacturer's instructions. The castings were performed in an induction-casting machine (Neutrodyn Easyti) using a Co-Cr alloy (Co 63.3–Cr 24.8–W 5.3–Mo 5.1–Si < 1–Fe < 1–Ce < 1, Wirobond C, BEGO). After devesting, the castings were blasted with 110 µm AlO_2 and finished with carbide burs (Komet, Gebr. Brasseler). Before ceramic veneering, the castings were blasted again with 110 µm AlO_2 with subsequent steamcleaning and fired with a ceramic bonder (Ceram-Bond, Bredent). Feldspar ceramics, Noritake (Noritake EX-3) or Duceram Plus (Duceram Plus, Degudent), were fused to the cores. Most FDPs were veneered with Noritake ceramics. The thickness of the veneering layer was 1.0 to 2.0 mm.

One hundred ninety FDPs were cemented with zinc phosphate cement (Harvard cement, Harvard Dental International) and 11 FDPs were cemented with self-adhesive modified composite resin (Rely X Unicem, 3M ESPE). The reason for using composite resin was not defined in the patient records.

Table 3 Lost to Follow-up During the 5-Year Period*

	Moved/new clinician	Deceased	No contact	Total
Patients (%)	4 (3)	10 (7)	10 (7)	24 (16)
FDPs (%)	4 (2)	14 (7)	11 (5)	29 (14)

*A further 7 FDPs were lost because of complications.

Results

Follow-up

Of 149 patients with 201 FDPs (supported by 743 abutments), 122 patients (82%) with 165 FDPs (82%) (supported by 609 [82%] abutments) were followed-up for 5 years. Twenty-four patients were lost to follow-up (see Table 3). Seven FDPs were not followed for 5 years due to complications; 1 FDP had a ceramic fracture at time of cementation, 1 FDP had 7

Table 4 Occurrence of Complications and Failures During 5-Year Follow-up

Complications	Patients (n = 149) (%)	FDPs (n = 201) (%)	Abutment teeth (n = 743) (%)	Failure survival†	Failure success‡
Biologic					
Caries	10 (6.7)	10 (5)	16 (2.2)		7
Gingivitis/mucosal	5 (3.4)	5 (2.5)	9 (1.2)		5
Periodontal	3 (2)	4 (2)	7 (0.9)		
Root fillings	7 (4.7)	7 (3.5)	8 (1.1)		
Extractions*					
Periodontal	2 (1.3)	3 (1.5)	6 (0.5)	1	2
Caries	2 (1.3)	2 (1)	8 (0.7)		1
Root fracture	2 (1.3)	2 (1)	2 (0.2)		
Technical					
Cementation failure	10 (6.7)	10 (5)	23 (3.1)	2	7
Cohesive ceramic fractures	7 (4.7)	7 (3.5)	7 units/8 fractures (0.7)	1	5
Tenderness	4 (2.7)	4 (2)	7 (0.9)		
Esthetic considerations	2 (1.3)	2 (1)	NA		

*One patient had caries complications in one FDP and root fracture in another FDP.
†Shortening of FDP (7), change of therapy (2).
‡Change of therapy (2).

abutment teeth extracted due to caries, 1 FDP had to be remade due to cement failure and tenderness of an abutment tooth, 1 FDP was lost due to trauma, and 3 FDPs had to be shortened to single crowns as a result of cement failure and change of therapy. A patient lost to follow-up could have more than 1 FDP, and a failed FDP could belong to a patient with another FDP that was considered a success. Therefore, the number of patients lost to follow-up is not coherent with the number of FDPs lost to follow-up. Accordingly, 7 FDPs were lost due to complications during the follow-up period and 165 FDPs were followed for 5 full years (Table 3).

Patient Record Registrations

The total number of complications per patient, FDP, and abutment tooth that occurred over 5 years (including the aforementioned early complications) is presented in Table 4. In total, complications occurred in 34 (23%) of 149 patients, 38 (19%) of 201 FDPs, and 60 (8%) of 743 abutment teeth. There were no framework fractures during the follow-up period. None of the 11 FDPs cemented with RelyX lost retention (23 abutments, 9 cantilever pontics, pontic/abutment ratio: 0.5 [4 of the abutments had received root canal treatment before cementation]). Ten (5%) of 190 FDPs cemented with zinc phosphate cement lost retention during the follow-up period. Six of these were cantilever FDPs (28 abutments, 12 distal cantilever pontics, pontic/abutment ratio: 0.5, mean cantilever pontics per FDP: 2, range: 1 to 4 [3 short-span FDPs and 3 long-span FDPs]) and, among these, 4 of the abutment teeth involved had received root canal treatment before cementation. Three FDPs were recemented, 2 were left without intervention (patients did not agree with suggested therapy to recement, FDPs were still in situ), 3 had a change of therapy (implants), and 2 were remade. There were no adhesive ceramic fractures. However, for 8 (0.7%) of 1,135 units in 7 (3.5%) of 201 FDPs, cohesive fractures were registered. Three fractures could simply be polished, 1 was untreated, 3 were treated with a corrective composite filling, and 1 was remade because of a fracture at cementation. Four of the fractures occurred in the maxilla, 4 in the mandible, 3 in the anterior region, and 5 in the posterior region. Sixteen (2.2%) of 743 abutment teeth in 5 (3.4%) of 149 patients (7 FDPs) were extracted. The reasons for extraction were periodontal problems related to 6 (0.5%) of 743 abutment teeth (in 2 patients), caries in 8 (0.7%) of 743 abutment teeth (in 2 patients), and root fractures in 2 (0.2%) of 743 abutment teeth (in 2 patients). Complications occurred in 33% of long-span FDPs (6 to 14 units), and 12% of the short-span FDPs (2 to 5 units).

Failures According to Success/Survival Definitions

One hundred forty-seven (73%) of 201 FDPs were considered to be successfull according to the success definition. Hence, 29 (14%) FDPs were considered failures. The reasons were: cohesive ceramic fractures (5), cementation failure (7), abutment teeth extracted (3), root fillings after cementation (5), change of therapy (2), and caries (7). The remaining 25 FDPs were lost to follow-up (reasons described in Table 3).

With the definition for survival applied to the material, 160 (80%) of 201 FDPs were considered survivals and 13 (6%) FDPs were considered failures during the 5-year follow-up. The reasons were: cohesive ceramic fracture at cementation (1), abutment teeth extracted due to caries (1), cementation failure and tenderness of abutment tooth (1), cementation failure and shortening to a single crown (1), change of therapy (2), and shortening of FDP (7). FDPs with a cohesive ceramic fracture were considered surviving if repair in the form of a composite correction or polishing was performed. The remaining 28 FDPs were lost to follow-up (reasons described in Table 3).

The 5-year CSRs for success and survival were 83.8% and 92.8%, respectively (Tables 5 and 6). The actual outcomes of the FDPs with the definitions described by Walton[22] are presented in Table 7.

Table 5 Cumulative Success Rate After 5-Year Follow-up

Period (y)	Examined FDPs	Dropout	Failed	CSR (%)	SE
Cementation	201	0	0	100.0	
1	188	5	8	95.7	1.5
2	181	2	5	93.0	1.9
3	167	6	8	88.5	2.4
4	157	7	3	86.8	2.5
5	147	5	5	83.8	2.8
Total	147	25	29	83.8	

SE = standard error.

Table 6 Cumulative Survival Rate After 5-Year Follow-up

Period (y)	Examined FDPs	Dropout	Failed	CSR (%)	SE
Cementation	201	0	0	100.0	
1	193	5	3	98.4	0.9
2	188	3	2	97.4	1.2
3	178	6	4	95.1	1.6
4	169	7	2	94.0	1.8
5	160	7	2	92.8	1.9
Total	160	28	13	92.8	

SE = standard error.

Table 7 The Six-Field Classification of the FDPs After 5 Years

Outcome	%
Success	79
Survival	0
Unknown	10
Dead	6
Repaired	1
Failed	4
Total	100

Discussion

This is a 5-year retrospective study of 201 Co-Cr FDPs provided for 149 patients between January 2000 and November 2005. Data were collected following an examination by one of the authors for 165 (82%) of the FDPs in 122 (82%) patients. All patient records were reviewed by two of the authors at least 5 years postcementation. The study was performed in a private clinical setting, which is of interest since most studies are performed by specialists at university clinics.[23] The FDPs were manufactured by one dental laboratory, and neither the dental clinic nor the dental laboratory changed materials significantly during the study period. All patients consecutively received Co-Cr FDPs when an FDP was constructed. Several limitations may be considered, such as the retrospective study design with the information recorded from the patients' dental charts without standardized evaluation criteria and the inclusion of all FDPs irrespective of length or position in the arch, which could result in several confounders. Another limitation is the absence of a control group. Instead, the results have been compared with similar studies on gold and Co-Cr alloys.[17,19,23–25]

No framework fractures were reported in this study. Only 8 cohesive fractures in 7 (0.7%) of 1,135 units or 7 (3.5%) of 201 FDPs were reported, and no adhesive ceramic fractures were found. This fracture rate is low compared with another study on FDPs. In a 3- to 7-year clinical evaluation of Co-Cr FDPs, 17.6% of FDPs had ceramic fractures.[17] However, those FDPs were placed in patients with compromised dentitions. No chipping was reported in a study following laser-sintered Co-Cr single crowns for 47 months.[19] In a systematic review of zirconia and conventional metal-supported FDPs, a high rate of chipping was reported, with 34% of metal FDPs suffering chipping after 3 to 5 years. However, the mean frequency of grade 3 chipping (severe chipping that led to replacement of the entire FDP) was 3.9%.[24] Another systematic review on conventional FDPs and cantilever FDPs estimated the 5-year ceramic fracture complication rate for conventional FDPs at 2.9% and cantilever FDPs at 3.5%.[23] These clinical results call into question the presumption that Co-Cr alloys would have a less favorable bond strength with the ceramic layer compared with high noble alloys.

Studies have reported that FDPs with cantilevers are more prone to cement failure.[26,27] In this study, 6 of 10 FDPs that suffered cementation failure were cantilever FDPs. Hence, 6 (8%) of 79 cantilever FDPs had cement failure compared with 4 (3%) of 122 noncantilever FDPs.

Very few gingivitis/mucosal problems were present (3.4% of patients, 1.2% of abutment teeth). Although this retrospective study did not record major biologic problems from the gingiva, a potential biologic risk should not be ignored. Several laboratory studies have reported on the elements released from base metal alloys.[7,12] However, conditioning in distilled water has been shown to reduce the elemental release from base metal alloys to the level of high noble alloys,[28] and the amounts of elements released may be well below the estimated daily dietary intake.[29] The clinical effect could therefore be less significant. A previous study on Co-Cr FDPs did not report any adverse reactions to the material.[17]

A systematic review revealed that studies on conventional high noble metal-ceramic FDPs displayed a 5-year survival rate of 93.8% and a 5-year success rate of 84.3%.[23] The results of the current study (survival rate of 92.8% and success rate of 83.8% after 5 years) are comparable with conventional high noble FDPs. The most common cause of complications reported in fixed prosthodontics is caries, followed by periapical involvement.[30] This is partly supported by the present study, where cementation failure was a complication in 10 (6.7%) of 149 patients and 23 (3.1%) of 743 abutment teeth, and caries in 10 (6.7%) of 149 patients and 16 (2.2%) of 743 abutment teeth. However, compared to other studies, the occurrence of caries was low.[25] This could be attributed to the clinic's recall system to a dental hygienist.

This study is based on Co-Cr FDPs manufactured using the lost-wax technique. It may be hypothesized that recent developments in CAD/CAM dentistry may further improve the clinical results due to a more controlled workflow: new manufacturing techniques have been adopted and the milling technique is already widely used,[14] while laser sintering seems promising.[19]

Conclusion

Co-Cr FDPs are a promising prosthodontic alternative to other dental alloys, presenting a low level of ceramic fractures, cement failure, caries, and other complications during the first 5 years in function. To evaluate their longer-term success and possible biologic adverse effects, further long-term randomized controlled studies are necessary. The research hypothesis that Co-Cr FDPs function well in a clinical setting during a follow-up period of 5 years is accepted.

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Literature Abstract

Water fluoridation and the association of sugar-sweetened beverage consumption and dental caries in Australian children

This study investigated the association between consumption of sugar-sweetened beverages (SSBs) and dental caries in a large and representative group of Australian children. A total of 16,857 children aged 5 to 16 years were included in this study. A questionnaire about each child's toothpaste use, toothbrushing frequency, exposure to fluoride sources, residential history, water consumption, socioeconomic status, and SSB consumption was completed by the respective parent or guardian. The children's dental statuses (number of decayed, missing, and filled deciduous and permanent teeth) were collected by dental staff of the School Dental Service clinics according to instruction manuals and training provided by the authors. The results showed: *(1)* SSBs consumption was highest among children who are male, older, from lower socioeconomic status, have parents with lower education, from regional and remote residences, and brush their teeth less frequently, *(2)* greater SSB consumption was associated with more dental disease in deciduous ($P < .001$) and permanent teeth ($P = .001$), *(3)* increase exposure to fluoridated water significantly reduced the association between SSB consumption and dental caries in deciduous teeth ($P = .001$) and permanent teeth ($P < .001$). The authors concluded that SSBs are a major risk factor for dental caries, and that community water fluoridation is beneficial in reducing the effect of SSBs on dental caries as well as preventing dental caries.

Armfield JM, Spencer AJ, Roberts-Thomson KF, Plastow K. *Am J Public Health* 2013;103:494–500. **References:** 34. **Reprints:** Jason M. Armfield, Australian Research Centre for Population Oral Health, School of Dentistry, University of Adelaide, Adelaide, South Australia, 5005 Australia. **Email:** jason.armfield@adelaide.edu.au—*Simon Ng, Singapore*