FIXED METAL CERAMIC PROSTHESES

Treatment need, complications and survival of conventional fixed prosthodontics

RITVA NÄPÄNKANGAS

Institute of Dentistry,
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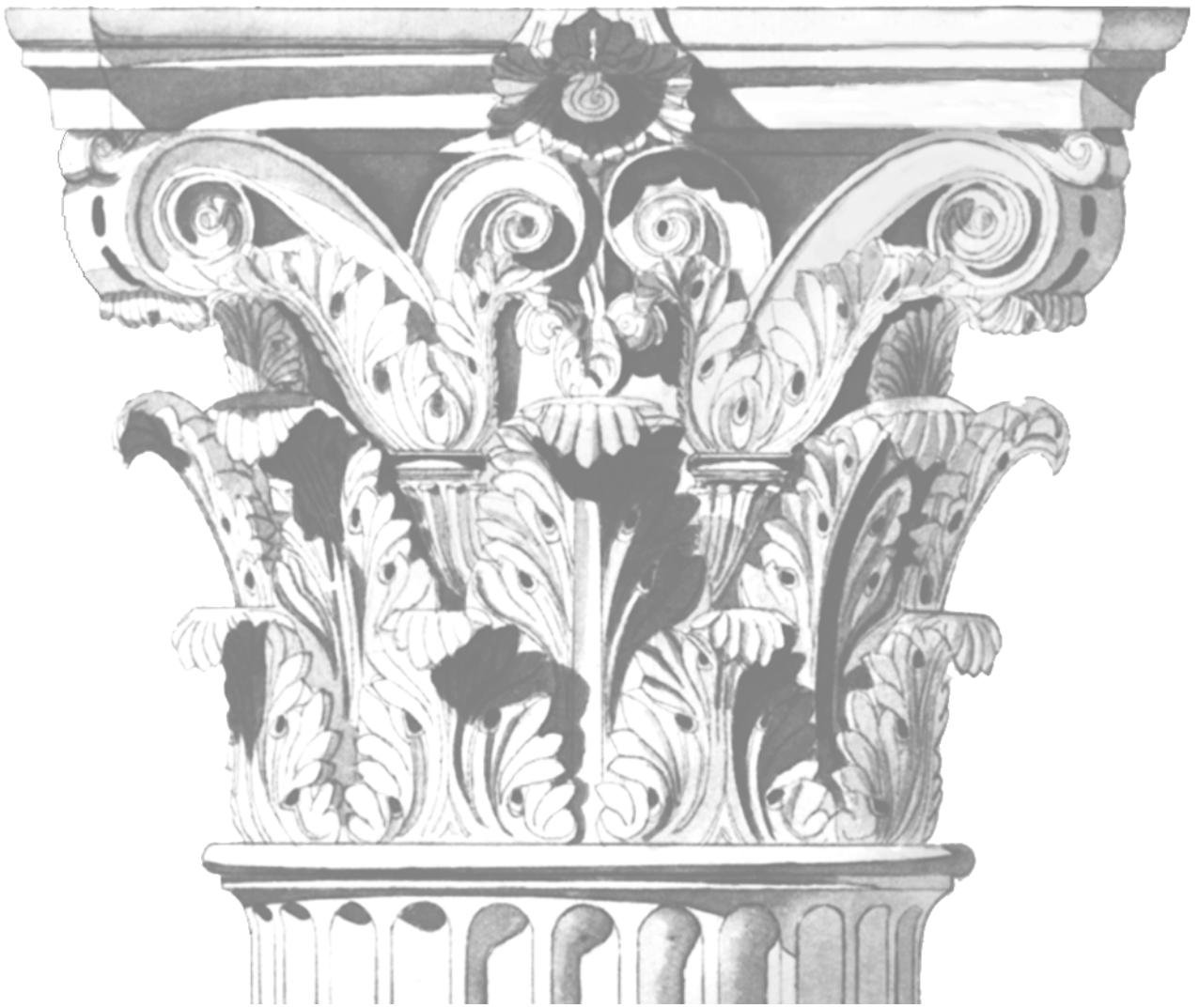

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Abstract

The aims of this study were to evaluate the treatment need of fixed bridges according to the distribution of pontics in dentition in different age groups, and to investigate the primary and late complications and survival of the conventional fixed metal ceramic prostheses, as well as patients' satisfaction with the prosthetic treatment.

The whole material consisted of the patients treated with fixed metal ceramic prostheses by undergraduate students at the Institute of Dentistry during the years 1984–1996. There were altogether 772 patients, 460 women (60 %) and 312 men (40 %). Their mean age was 47 years (23–81 years). Altogether 944 single metal ceramic crowns and 543 fixed bridges (1374 abutments and 807 pontics) were prepared.

It can be concluded that the fixed bridges are most often prepared to replace upper first premolars and lower first molars also in the future. The most usual primary complications related to fixed bridges occurred during preprosthetic endodontic treatment of abutment teeth and during the preparation of the root canals. Previous restoration of the prepared tooth does not have any marked effect on the prognosis of single crowns with dowels, although anatomically complicated upper lateral incisors and upper first premolars need special attention in the treatment planning. Patients were satisfied with aesthetics and function of the fixed metal ceramic prostheses. Late complications found in clinical examinations were few, and the survival rate for the fixed metal ceramic bridge prostheses was calculated to be 84 % after 10 years, long fixed bridges having a lower survival than the shorter ones.

The treatment need for conventional fixed bridges seems to be highest among patients over 50 years of age in the future. Age does not influence the longevity of the fixed prostheses, but basic circumstances of the mouth, especially low secretion of saliva affected by diseases and/or medications and high scores of lactobacilli and streptococcus mutans of the saliva seem to decrease the survival.

Keywords: crowns, follow-up studies, fixed partial dentures, survival analysis, treatment need

Tietä käyden tien on vanki.
Vapaa on vain umpihanki.
- Aaro Hellaakoski -

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Oulu, November 2001 Ritva Näpänkangas

List of original publications

This thesis is based on the following articles, which are referred to in the text with Roman numerals:

I Näpänkangas R, Salonen-Kemppi MAM & Raustia AM. Treatment need for fixed metal ceramic bridge prostheses in patients treated by dental students in 1984 – 1996. J Oral Rehabil, in press

II Raustia AM, Näpänkangas R & Salonen MAM (1998) Complications and primary failures related to fixed metal ceramic bridge prostheses made by dental students. J Oral Rehabil 25: 677-680

III Näpänkangas R, Salonen MAM & Raustia AM (2000) Influence of previous restoration of the tooth on prognosis of crowns with dowels. J Oral Rehabil 27: 1042-1046

IV Näpänkangas R, Salonen MAM & Raustia AM (1997) A 10-year follow-up study of fixed metal ceramic prosthodontics. J Oral Rehabil 24: 713-717

V Näpänkangas R, Salonen-Kemppi MAM & Raustia AM. Longevity of fixed metal ceramic bridge prostheses: a clinical follow-up study. J Oral Rehabil, in press

Contents

1 Introduction

Fixed prosthodontics includes restorations which are permanently cemented onto the teeth. A single crown is an extracoronal restoration which veneers the clinical crown, or when the clinical crown has been destroyed, forms a clinical crown, and the reconstruction is supported into the root with a dowel. A fixed bridge (called also as fixed bridge prosthesis, bridge or fixed partial denture) is attached to remaining teeth to replace a missing tooth, and teeth serving as attachments for a fixed bridge are called abutments. The part of the fixed bridge which veneers the abutment tooth is called a retainer and the part which replaces a missing tooth is called a pontic. (Shillingburg *et al.* 1997.)

All-ceramic crowns, so-called jacket crowns, have been used widely in dentistry since 1903 and the technique of fusing porcelain to metal was introduced in the 1950s (O'Brien 1997). Nowadays metal ceramic restorations have replaced the formerly used acrylic resin veneer restorations on the basis of better aesthetics and resistance to wear, although the increasing demands of aesthetics provide an opportunity for a comeback of all-ceramic fixed prostheses.

In a large number of studies concerning implantology conventional fixed prosthodontics has recently been largely overlooked in the literature, and only few studies have been introduced about the survival of conventional fixed prosthodontics in the last few years. Although implantology has a great demand and supply, implants do not solve every problem in oral rehabilitation and the conventional fixed prostheses still have their place in treatment planning. In addition, numerous new materials are constantly being developed for crowns and fixed bridges as well as for cementation.

In Finland there are only few studies dealing with fixed prosthodontics. Ettala-Ylitalo (1987) investigated the occlusal interferences and TMJ dysfunction in patients treated with fixed prostheses. Ranta (1987) analysed the extent of different types of prosthetic rehabilitation, including fixed prostheses, among the Finnish population as part of the Mini-Finland Oral Health Survey, and Nevalainen *et al.* (1996) evaluated the prosthetic reconstructions among 76 – 86-year-old inhabitants of Helsinki. In the Oulu area the prosthetic treatment need of adults was investigated by Tervonen (1988b) and Hartikainen (1994). Although follow-ups of as long as 25 years have been carried out in other countries, no such study is available in Finland. The rarity of follow-up studies can be assumed to be related to difficulties in gathering material, because the data available

concerning the dental treatment of patients in health centres and private practices are restricted by difficulties in getting the suitable data, as well as by the incoherence in records and notes. At the Institutes of Dentistry the patient records are recorded in the same way and the treatment plans and treatment phases go along the same lines, which provides an extensive material to be evaluated.

2 Review of literature

2.1 Epidemiology

Oral rehabilitation using fixed prosthodontics has not been studied much in oral epidemiology, and only few studies have been introduced of the production of prosthetic treatments, i.e. how many units of different types of prosthetic appliances are fabricated within a specified period or for a certain population (Farrell & Dyer 1989, Fyffe 1992, Silness & Berge 1990). On the other hand, the prevalence for caries and gingivitis/periodontitis has been widely evaluated in many countries and in relation to these, tooth losses or missing teeth, as well as edentulousness or denture wearing have been studied (Laine & Murtomaa 1985, Tervonen 1988a, Björn & Öwall 1979, Ranta 1987).

In Finland only few epidemiological studies are found concerning fixed prosthodontics. In the Mini-Finland Oral Health Survey during the years 1977 - 1980 Ranta *et al.* (1986) found that 10.9 % of the subjects over 30 years of age had single crowns and 3.7 % had fixed bridges. In the study from the Oulu area and Osthrobotnia in 1982 - 1983 2 % of the 25 – 65-year-old residents had one or more fixed bridges and 3 % had one or more single crowns (Tervonen 1988b). In 1988 - 1990 in the Oulu area 5 % of the 65 year-old residents had fixed bridges and 7 % had single crowns (Hartikainen 1994). The numbers in Southern Finland in the Helsinki area differ from the Oulu area: Nevalainen *et al.* (1996) evaluated prosthetic reconstructions among the 76 – 86-year old inhabitants in 1989 – 1991 and found that 24 % of the whole population and 45 % of the dentate population had fixed prostheses (43 % had a single crown and 18 % had a fixed bridge). In Sweden the number of fixed prostheses was already higher than in Finland in 1979, when 28 % of the dentate persons had a fixed bridge in the upper jaw and 10 % had one in the lower jaw (Björn & Öwall 1979). Sweden has a National Insurance System, which has supported dental treatment including the prosthetic treatment of Swedish residents since 1974, while in Finland the prosthetic treatment of war veterans has only been financially supported since 1994.

2.2 Treatment need

The evaluation of treatment need is difficult, because a missing tooth or teeth do not subjectively require replacement with prosthesis in all cases. In the anterior segment of both jaws the need for replacement is obvious for aesthetical reasons, but in the premolar-molar areas a missing tooth/teeth do not always constitute the primary subjective indication for replacement. In the study of Tervonen (1988a) in the Osthrobothnia area in Finland subjective replacement need was found in one out of four of the subjects with missing anterior teeth or premolars. On the other hand, the open space due to an extracted tooth can be partly closed by tooth migration, and related to this, Björn and Öwall (1979) reported that 20 % of missing teeth had not resulted in a remaining tooth space. However, tooth migration and elongation may cause severe disturbances in occlusal relationships.

The costs for fixed prostheses are quite high, and this may prevent the ideal treatment in many cases. Ranta *et al.* (1986) concluded that oral rehabilitation with fixed prostheses seemed to be associated with social and economic background. The situation has been the same in Sweden despite the National Insurance System which supports dental treatment (Hanson *et al.* 1994).

2.3 Materials used in fixed prosthodontics

2.3.1 Porcelain fused to metal

Porcelain fused to metal provides better aesthetics in fixed prosthodontics than the acrylic resin veneers that were used formerly (Shillingburg *et al.* 1997). It has been pointed out that a significant number of failures in acrylic resin veneer retainers were due to the appearance, wear or deterioration of the resin (Schwartz *et al.* 1970). In the study of Palmqvist & Swartz (1993) more acrylic resin veneer fixed prostheses than metal ceramic ones were lost after 18 - 23 years, and wear was considered to be the significant factor. The risk for loss of acrylic resin veneer fixed prosthesis has been estimated to be as much as 44 times higher than for metal ceramic ones (Palmqvist & Söderfeldt 1994). On the other hand, porcelain is more brittle than the resin, and occasional porcelain fractures or mechanical failures of the bonding of porcelain to a gold alloy could happen. Such primary failures tend to occur during the period from the first month up to a couple of years (Reuter & Brose 1984).

Porcelain has been noted to cause more enamel wear than gold restorative materials, amalgam or composite materials (Hudson *et al.* 1995, Jagger & Harrison 1995a, Hacker *et al.* 1996). In acid environment the wear is even greater (Ratledge *et al.* 1994, Jagger & Harrison 1995b), and it has been observed that there are differences in the abrasive properties even among different porcelains (Hacker *et al.* 1996, Metzler *et al.* 1999). It has been recommended that after occlusal adjustment the porcelain restoration should be re-glazed or carefully polished to avoid abrasive surface of the porcelain (Al-Wahadni & Martin 1999).

2.3.2 Core materials

The restoration usually covers a minor part of the abutment tooth, and the major part of the abutment tooth is natural tooth structure. When the restoration increases the retention and resistance provided by the remaining tooth structure, it is described as core reconstruction (Morgano & Brackett 1999). The core material can be reinforced with parapulpal pins, and when the tooth is endodontically treated, the core reconstruction is in most of the cases reinforced with dowels. Besides the cast dowel and cores the direct core materials presented for abutments of fixed prosthodontics are glass ionomer-based materials, silver amalgam and composite materials. Glass ionomer-based materials, even reinforced with silver amalgam, have low compressive, tensile and flexural strengths, and thus perform poorly as core material (Kovarik *et al.* 1992, Levartovsky *et al.* 1994, Ziebert & Dhuru 1995, Cohen *et al.* 1996, Gateau *et al.* 1999, Cho *et al.* 1999). Silver amalgam has been reported to have high compressive strength and rigidity as a core material (Kovarik *et al.* 1992, Gateau *et al.* 1999), but general health concerns about its mercury content are currently of interest (Council on Scientific Affairs 1998).

Development of composite materials has led to good compressive and tensile strengths for the composites (Cho *et al.* 1999) and they are widely used nowadays. These materials are beneficially more flexible than silver amalgam (Kovarik *et al.* 1992), but this feature also limits their use when there is not enough supporting dentin, although they can be bonded to teeth using dentinal adhesives. Recently presented glass fiber reinforcements enhance the flexural properties of composite materials (Vallittu 1999). Unfortunately, the biological effects of the composites need further research (Söderholm & Mariotti 1999), and although the incidence of allergies caused by composite materials is rare among patients, case reports of allergies among dental personnel are increasing (Alanko *et al.* 1996, Bruze 1994, Björkner & Niklasson 1997, Kanerva *et al.* 2000).

2.3.3 Dowels

An endodontically treated tooth usually requires a dowel to provide adequate retention, because axial dentin reduction of a crown preparation combined with an endodontic access preparation frequently leaves insufficient tooth substance to support a crown (Shillingburg *et al.* 1997). The dowels used can be parallel-sided or tapered, prefabricated or custom-cast. Parallel-sided dowels have in several studies been noted to be more retentive than tapered ones (Standlee *et al.* 1978, Sorensen & Martinoff 1984b, Johnson & Sakumura 1978, Torbjörner *et al.* 1995), but parallelism may result in overpreparation of the apical third (Tilk *et al.*1979) or in the coronal part of the root channel (Gluskin *et al.* 1995). Therefore, perforations and oblique root fractures are quite common complications (Assif *et al.* 1993).

In fixed bridges tapered, custom-cast dowels are widely used, and in clinical follow-up studies long-term clinical results have been positive (Mentink *et al.* 1993, Torbjörner *et al.* 1995). However, custom-cast dowels have seemed to increase the risk for root fractures when compared to more elastic dowels (Martinez-Insua *et al.* 1998, Sirimai *et al.* 1999), but on the other hand, the morphological design of custom-cast dowels is less

likely to result in post fracture (Fraga *et al.* 1998). Besides the design of the dowel the amount of remaining tooth structure has been shown to be an important factor in resistance to root fracture (Sornkul & Stannard 1992). It is important to extend the preparation margin of the crown 2 mm apical to the junction of the core and tooth (ferrule effect) to share the stresses and to prevent vertical fracture in the root canal (Sorensen & Engelman 1990, Milot & Stein 1992, Morgano & Brackett 1999).

2.3.4 Dental cements

The cements used in fixed prosthodontics include zinc phosphate, zinc oxide-eugenol, polycarboxylate, glass ionomer, resin-modified glass ionomer, and resin cements. The zinc oxide-eugenol cements are used for temporary cementation, other cements for final cementation. The clearly most commonly used cement is zinc phosphate cement, having a long history since the early years of the 20th century (O'Brien 1997). Good long-term clinical results are convincing, and zinc phosphate cement is used in many studies as control for newer cements. The main advantages of the zinc phosphate cement are its good manipulation properties, its short enough setting time, thin cement layer (Staninec *et al.* 1988) and adequate strength properties. A clear disadvantage is high acidity of the cement in the early setting phase, which may cause pulp irritation, and the pressure in the root canal during the cementation has been measured to be higher with zinc phosphate cement than with resin or glass ionomer cements (Morando *et al.* 1995). In addition, the zinc phosphate cement is brittle and has solubility in oral fluids (Yoshida *et al.* 1998). The adhesion is purely mechanical, no chemical bond is achieved, and the microleakage of the zinc phosphate cement is greater than with resin-modified glass ionomer cements or resin cements (White *et al.* 1994). (O'Brien 1997.)

The absence of chemical bond of the zinc phosphate cement influenced the development of polycarboxylate and glass ionomer cements in the 1960s and 1970s (O'Brien 1997). Polycarboxylate cement has a weak chemical bond to dentin and its pulp irritation is lower than with zinc phosphate cement. On the other hand, polycarboxylate cements have been shown to be more flexible than zinc-phosphate cements, they have quite high solubility in oral fluids and they exhibit large plastic deformation, which is regarded to be a clear disadvantage (Branco & Hegdahl 1983, Yoshida *et al.* 1998).

The promising advantage of glass-ionomer cements is the ability to release fluoride, although there is considerable variation in fluoride release between the different glass-ionomer based materials, and the inhibition of dental caries by this fluoride release is questionable (Muzynski *et al.* 1988). The cumulative fluoride release has been observed to increase with time (Musa *et al.* 1996). The glass-ionomer cements have potential adhesive characteristics, which may vary between different glass-ionomer cements (O'Brien 1997). Resin-modified glass-ionomer cements have similar chemical properties (Musa *et al.* 1996). Disadvantages are moisture sensitivity, radiolucency and possible pulpal sensitivity due to prolonged initially low pH and the effects of toxic ions (O'Brien 1997, Kern *et al.* 1996).

Resin cements are the newest cements and their advantages are low solubility in oral fluids (Yoshida *et al.* 1998), as well as high micromechanical and chemical bonding to

tooth surfaces and ceramic surfaces (O'Brien 1997). The setting of the resin cements is either chemical, light-activated or dual-cured. In dual-cured materials the chemical setting is included alongside the light activating. This procedure has been shown to be more effective than chemical curing alone (Darr & Jacobsen 1995). Mechanical properties have been widely studied, and it seems that in tensile force the resin cements are inferior to zinc-phosphate and glass-ionomer cements (Radke *et al.*1988), although opposite results have also been obtained (Duncan & Pameijer 1998), and tensile forces vary between the resin cements (Mendoza & Eakle 1994, O'Keefe *et al.* 2000, White & Yu 1993). Clear disadvantages are possible biological effects, which include allergy and pulp sensitivity due to polymerisation contraction and possible microleakage (O'Brien 1997). The resin cements have also appeared to imbibe water and expand with time (Small *et al.* 1998) Other disadvantages are critical manipulation properties, higher film thickness than with traditional cements (Staninec *et al.* 1988) and difficulty in removal of excess cement (O'Brien 1997).

The zinc-oxide eugenol cements are used only for temporary cementation because they have low strength, low abrasion resistance and high solubility in oral fluids. The advantages of zinc-oxide eugenol cements are their adequate manipulation properties, their long enough setting time (moisture is required for setting), good sealing ability and resistance to marginal penetration. Another advantage of these materials is stated to be the bland effect on pulp tissues due to eugenol (O'Brien 1997). However, eugenol is no longer present in newest temporary cements, because eugenol could inhibit the setting process of dental resins (Tjan & Nemetz 1992). Eugenol is also a potential allergen (Kallus & Mjör 1991).

2.4 Primary complications related to fixed prostheses

Few papers have been published concerning the primary complications in adjunction to fixed prosthodontics. Öwall *et al.* (1992) evaluated the prosthetic claims based on the Swedish Patient Insurance Scheme to find primary complications related to the prosthetic treatment. Altogether 136 reported cases of the Scheme in 1989 were evaluated, and there were 12 reports of treatment injuries. In seven reports out of 12 there was a root perforation during preparation for post, and in two cases a root was fractured during cementation of the post. Vital preparation fractures had occurred in two cases during try-in or cementation of fixed bridge, and in one case oral mucosa was injured during the preparation phase.

The primary complications of 36 long fixed bridges (eight units or more) reported in the Swedish Patient Insurance Scheme were analysed by Öwall & Cronström (2000). The complications were restricted to have occurred no more than two years after cementation. The highest proportion of the complications were metal framework fractures (41 % of cases). Other complications were loss of retention (24 %), porcelain fractures (17 %) and tooth/root fractures (10 %). Seven percent of the cases were classified as miscellaneous.

2.5 Late complications and survivals of single crowns and fixed bridges

Late complications have been reported in many follow-up studies shown in Table 1. Besides the clinical follow-ups, late complications and survivals of fixed bridges have been evaluated using patient files (Leempoel *et al.* 1995, Libby *et al.* 1997), prosthodontic claims (René *et al.* 1991, Öwall *et al.* 1992) and questionnaires (Randow *et al.* 1986). Most of the studies include both metal ceramic and acrylic resin veneer fixed prostheses, and the follow-up time varies from one to 25 years. In addition, most of the studies focus on fixed bridges, the survival of single crowns was studied only by Palmqvist & Swartz (1993), who concluded that 92 % of the single crowns were still in place after 18 – 23 years. The reason for the removal of single crowns during the follow-up time remained unknown.

The most usual reason for removals of fixed bridges is caries (Schwartz *et al.* 1970, Randow *et al.*1986, Walton *et al.* 1986, Libby *et al.* 1997). Loss of retention, which has been noted to be related to caries (Karlsson 1986, Karlsson 1989, Lindquist & Karlsson 1998), is also a common reason for failures (Valderhaug 1991, Glantz *et al*. 1993, Öwall *et al.* 1992). Other frequent causes for failures are poor aesthetics, technical problems (fractures of the fixed bridges, porcelain fractures, wear of occlusal surfaces), endodontic treatment through the retainer, and periodontal diseases (Reuter & Brose 1984, Randow *et al.* 1986, Karlsson 1989, Cheung *et al.* 1990, Valderhaug 1991, Walton *et al.* 1986, Glantz *et al.* 1993, Palmqvist & Swartz 1993, Libby *et al.* 1997, Lindquist & Karlsson 1998, Öwall *et al.* 1992). The survival percent of the studies varies from 2.9 % - 7.1 % per year to 68 % after 15 years and to 65 % or 79 % after 20 years (Table 1). To diminish the variation of the different follow-ups, the survivals of the studies have been combined by meta-analytical procedures by Creugers *et al.* (1994) and Scurria *et al.* (1998). Creugers *et al.* (1994) calculated the survival rate to be 74.0 ± 2.1 % after 15 years. The results of Scurria *et al.* (1998) were quite similar to Creugers *et al.* (1994): the survival rate was 92 % after 10 years and 75 % after 15 years.

2.5.1 Location of the complications

According to previous studies, failures in fixed bridges occurred mainly in upper anterior and lower posterior segments (Cheung *et al.* 1990) and in last abutments more often than in intermediate ones (Karlsson 1986, Palmqvist & Swartz 1993). In the evaluation of technical failures the majority of fractures of the reconstructions occurred also in the region immediately mesial to the distal abutment teeth, especially with cantilever extension pontics (Randow *et al.* 1986). According to Cheung *et al.* (1990) endodontic failures affect mostly the upper anterior fixed bridges, while in the study of Palmqvist & Swartz (1993) endodontic complications were more frequent in mandibular abutment teeth than those in the maxillae.

Recorded complications and survivals concerning the cantilever extension pontics are varying. Although fixed bridges with cantilever extension have been shown to be better in

occlusion and in the risk for caries than removable partial dentures (Budtz-Jorgensen & Isidor 1990), Karlsson (1989) concluded that technical failure and replacement of the fixed bridges is more frequent for restorations with cantilever extension pontics (33.3 % of failures) than for those with a distal end abutment (11.5 % of failures), also noted by Öwall & Cronström (2000). The failure risk was even more emphasised when cantilever extension pontic was in combination with an endodontically treated terminal abutment tooth (Randow *et al.* 1986, Karlsson 1989). On the contrary, in the follow-up studies of Sundh & Ödman (1997) and Leempoel *et al.* (1995) the cantilever extension pontic did not increase the failure rate, and in the study of Palmqvist & Swartz (1993) even two cantilever extension pontics did not have a negative influence on the survival of fixed bridges.

When opposing occlusion is evaluated in relation to complications of fixed bridges, the longest survival of fixed bridges was with opposing complete dentures because of reduced forces of occlusion (Schwartz *et al.* 1970). On the other hand, in the study of Randow *et al.* (1986) there was no significant relationship between the failure rate and the type of dentition of the opposing jaw.

Table 1. Follow-up studies concerning fixed prostheses

author	year	type of the examination	country	providers	number of patients	mean age	fixed bridges	single crowns	metal ceramic / acrylic resin veneer (%)	follow-up time (years)	survival (%)
Reuter & Brose	1984	clinical	United Kingdom	general practitioners	..	..	121	..	not mentioned	0-10	failures 2.9 % per year
Randow et al.	1986	questionnaire	Sweden	general practitioners	239	52	316	..	12/88	6-7	-
Karlsson	1986	clinical	Sweden	general practitioners	164	58	238	..	25/75	10 *	93.3
Karlsson	1989	clinical	Sweden	general practitioners	97	64	140	..	not mentioned	14 *	83
Cheung et al.	1990	clinical	Hong Kong	dental students	143	39	156	..	not mentioned	0-5	failures 7.1 % per year
Foster	1990	clinical	United Kingdom	general practitioners	130	..	142	..	not mentioned	..	-
Valderhaug	1991	clinical	Norway	senior students	55	..	59	..	0/100	15	68
Glantz et al.	1993	clinical and/or interview	Sweden	general practitioners	52	65	..	..	not mentioned	15	67.5
Palmqvist & Swartz	1993	clinical	Sweden	senior students	66	..	103	25	34/66	18-23	79 **
Leempoel et al.	1995	patient files	Netherlands	general practitioners	1080	63	1674	..	not mentioned	1-12	87
Libby et al.	1997	clinical and patient files	USA	prosthodontists	50	63	89	..	100/0	1-25	-
Sundh & Ödman	1997	clinical	Sweden	dental students	70	..	103	..	15/85	18	75
Lindquist & Karlsson	1998	clinical	Sweden	general practitioners	72	70	140	..	not mentioned	20 *	65

* studies based on the same basic study group which is followed

** the survival of metal ceramic restoration

3 Aims of the study

The aims of the study were

1. to investigate the treatment need of fixed bridges according to distribution of pontics of bridges, i.e. missing tooth/teeth and in different age groups in the years 1984 - 96

2. to investigate primary complications during the preprosthetic and prosthetic treatment and shortly after the treatment, i.e. six months afterwards

3. to evaluate the effect of previous restoration of the tooth on prognosis of single crowns with dowels

4. to evaluate late complications and survival of the fixed metal ceramic prostheses as well as patient satisfaction with the results of the treatment

4 Material and methods

4.1 The description of the entire material

The material consisted of the patients who were treated with fixed metal ceramic prostheses by undergraduate students during the years 1984 – 1996 at the Department of Prosthetic Dentistry and Stomatognathic Physiology, Institute of Dentistry, University of Oulu, Finland. There were altogether 772 patients, 460 women (60 %) and 312 men (40 %), the mean age of the patients was 47 years and the age variation was 23 – 81 years (Fig. 1). The time period was limited to begin from the date when fixed metal ceramic prostheses began to be prepared by undergraduate students in 1984 and to end at the end of the year 1996, including the six-month follow-up examinations performed in the year 1997. No acrylic resin veneer prostheses, full metal single crowns or all-ceramic single crowns were included in this study. Full metal crowns were accepted only as retainers.

The basic data of the patients and the prosthetic treatment were recovered from the patient files. The detailed formula of the study is shown in Appendix 1. The data included anamnestic data, data from the clinical examination and the treatment performed. The prosthetic treatment was recorded phase by phase: treatment planning, preprosthetic procedures, preparation procedures and the cement used were registered. The information of the six-month follow-up was also recorded, and if the patient had had treatment after the basic prosthetic treatment related to these prostheses at the Institute of Dentistry, i.e. treatment of complications, loss of retention etc., the data concerning these procedures were also recorded.

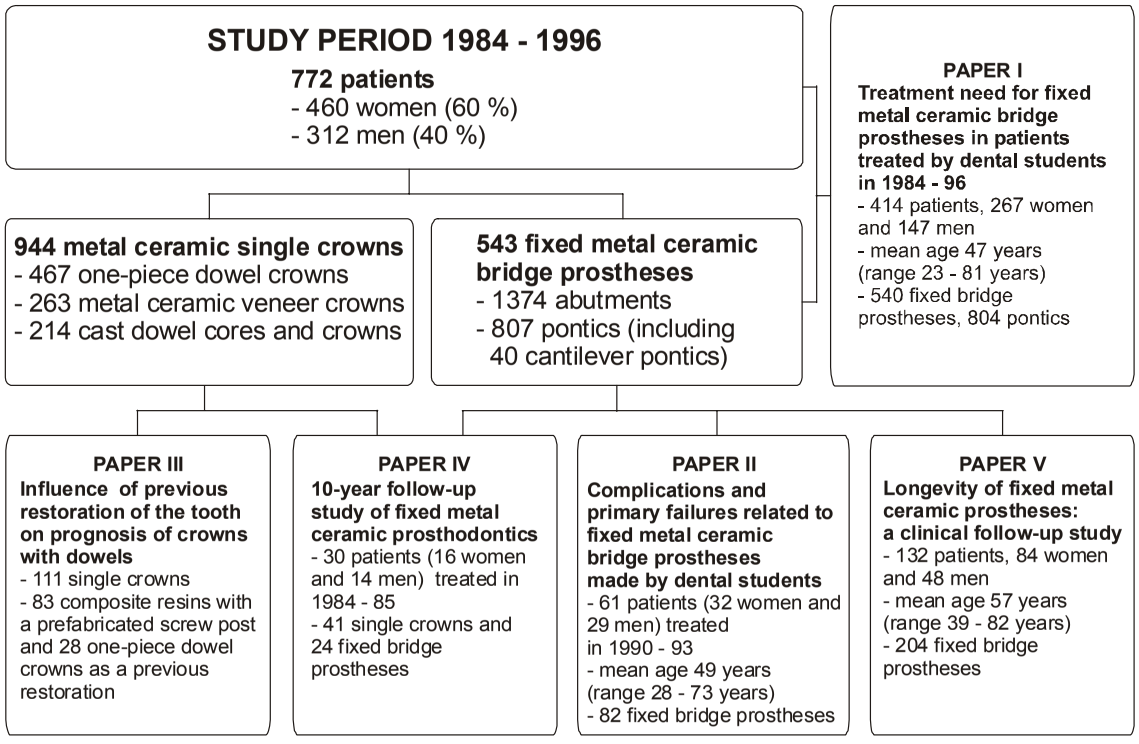


Fig. 1. The definition of the entire study group including the distribution of gender of the patients, single metal ceramic crowns and fixed metal ceramic bridges, as well as the definition of the material of the Papers.

4.1.1 The single metal ceramic crowns

Altogether 944 single metal ceramic crowns were prepared during the years 1984 – 1996 for 404 patients (235 women (58 %), 169 men (42 %), mean age 49 years, range 25 – 77 years). There were 467 metal ceramic one-piece dowel crowns (50 %), 263 metal ceramic veneer crowns (28 %) and 214 metal ceramic crowns with cast dowel and cores (22 %). Most of the patients were treated with one crown (55 %), but there were also patients treated with as many as 10 crowns (1 %).

The most usual reason for treatment with a single metal ceramic crown was large restoration in the tooth (44 %) (Table 2). Reasons for treatment also included fractured restoration or fractured tooth (16 %), strengthening of the abutment tooth for removable partial prosthesis (13 %) and aesthetical reasons (7 %).

Table 2. Reasons for treatment with single metal ceramic crowns in patients treated at the Institute of Dentistry during the years 1984 – 96.

Reason	n	%
Large restoration	414	44
Fractured restoration / tooth	154	16
Abutment tooth for removable prosthesis	123	13
Aesthetics	70	7
Renewal of old crowns	65	7
Worn tooth	50	5
Correction of occlusion plane	44	5
Injury	15	2
Symptoms of TMJ	4	0.4
Allergy to formaldehydes	4	0.4
Transplantation	1	0.1
Total	944	100

Former restoration of the tooth treated with a single metal ceramic crown was most frequently composite resin (363 teeth, 40 %) and the composite resin was supported by a screw post in 10 % of all former restorations (94 teeth). Amalgam was used in 32 % of the teeth (294 teeth), and in 10 % of the teeth (87 teeth) there was a former single crown. In 8 % of the teeth (73 teeth) the tooth was without a restoration, or only a minor part of the tooth had been restored.

The distribution of the single metal ceramic crowns in dentitions is shown in Fig. 2. Most of the single crowns prepared during the years 1984 – 96 were prepared in the upper central and lateral incisors. Other commonly prepared teeth in upper jaw were upper first premolars. In lower jaw most of the single crowns were prepared in first and second premolars.

The most common cement used for cementation of single crowns was zinc-phosphate cement (Lumicon®, 77 %). Other commonly used cements were resin cement (F21®, 11 %) and glass ionomer cement (Fuji®, 2 %). In 17 cases (2 %) the single crown could not be loosened from the temporary cement (zinc oxide cement, Temp-Bond®).

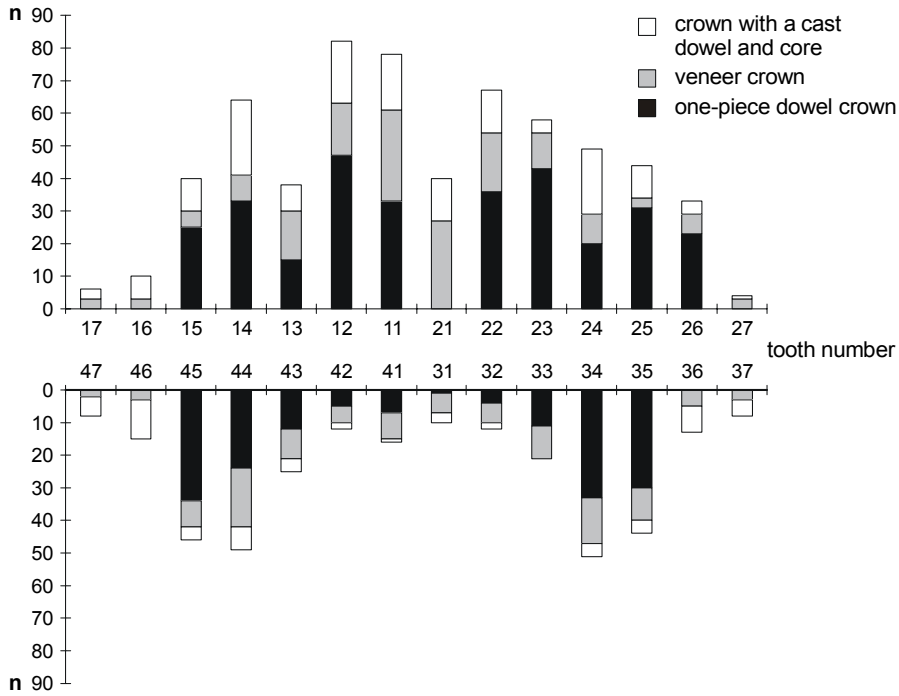


Fig. 2. The distribution of the metal ceramic single crowns in dentition.

4.1.2 The fixed metal ceramic bridges

Altogether 543 fixed metal ceramic bridge prostheses were prepared during the years 1984 – 96 for 414 patients (267 women (65 %) and 147 men (35 %), age range 23 – 82 years, mean 47 years). Fixed bridges included altogether 1374 abutments and 807 pontics (including 40 cantilever extension pontics) showing the abutment-pontic ratio to be 1.7 : 1. There was a metal ceramic veneer retainer in 94 % and a full metal (gold) retainer in 6 % of all abutments. Most of the fixed bridges consisted of three units and the longest fixed bridge prepared by a dental student was 11 units. In upper jaw there were 370 fixed bridges (68 %, abutment-pontic ratio 1.7 : 1) and in lower jaw 173 fixed bridges (32 %, abutment-pontic ratio 1.7 : 1).

The most usual reason for treatment with fixed bridge was the patient's interest to replace tooth/teeth extracted before the treatment at the Institute of Dentistry (61 %) (Table 3). Other common reasons were replacement of the removable prosthesis (7 %) and tooth extraction at the Institute of Dentistry because of large fracture (7%), periodontitis (5 %) or deep caries (5 %).

Table 3. Reasons for treatment with fixed metal ceramic bridges (counted by pontics) in patients treated at the Institute of Dentistry during the years 1984 - 96.

Reason	n	%
Formerly extracted tooth/teeth	493	61
Replacement of removable prosthesis	58	7
Extraction for a fracture of the tooth	55	7
Symptoms of TMJ	43	5
Extraction for periodontal reasons	42	5
Extraction for deep caries	41	5
Renewal of the fixed bridge	26	3
Injury	17	2
Inherent missing tooth/impaction of the tooth	12	1
Perforation in preparation of the root canal	9	1
Perforation in root canal therapy	8	1
Worn teeth	7	1
Aesthetics	3	0.4
Total	807	100

The distribution of abutment teeth in dentition is shown in Fig. 3. The most often used abutments were upper canines, which constituted 19 % of all abutments. The distribution of pontics is shown in Fig. 4. The most common pontic was upper left first premolar (11 % of all pontics). Other common pontics were lower first molars (left one 9 % and right one 7 %), upper right premolars (first one 9 % and second one 8 %) and upper left second premolar (8 %). Cantilever extension pontics were mostly used in the anterior segment of the upper jaw.

The most usual cement used for cementation of fixed bridges was zinc-phosphate cement (Lumicon®, 77 %). Other commonly used cements were resin cement (F-21®, 5 %) and glass ionomer cement (Fuji® , 5 %).

Natural dentition was present in occlusion against the fixed bridges in most of the cases (79 %). 10 % of the patients had a removable partial denture, 9 % had another fixed bridge and 2 % had a complete denture against the fixed bridge.

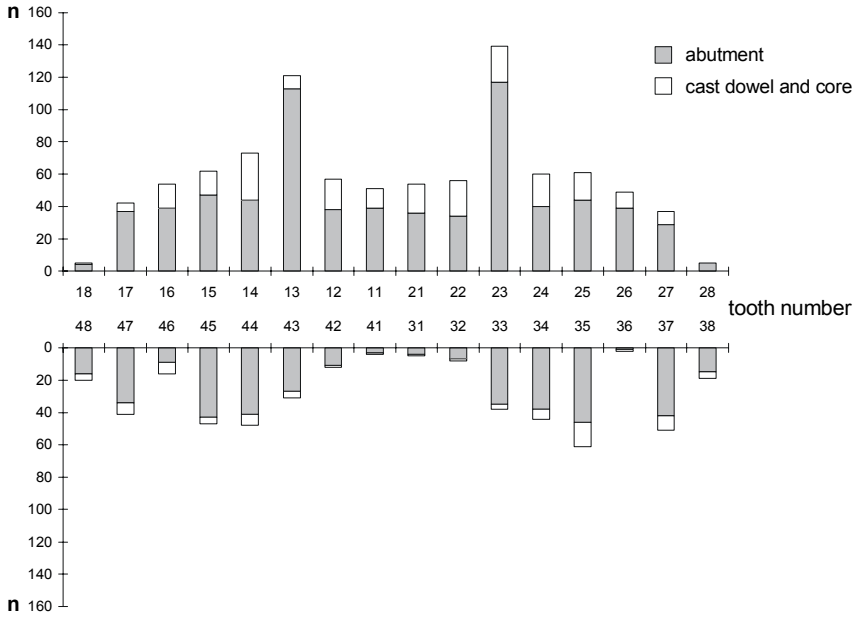
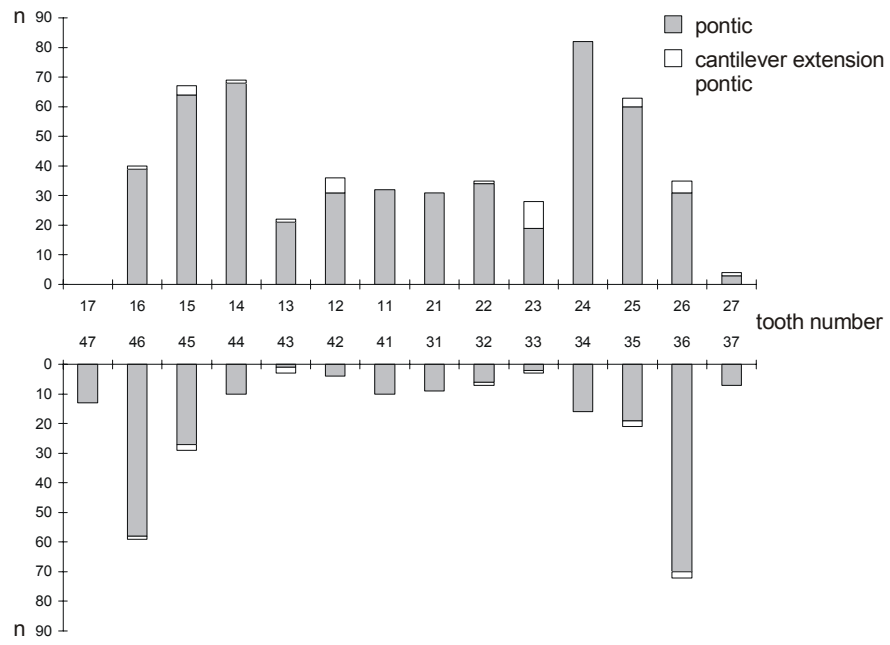


Fig. 3. The distribution of the abutment teeth in dentition

Fig. 4. The distribution of the pontics and cantilever extension pontics in dentition.



4.2 Material and methods of the Papers

4.2.1 Paper I

The treatment need for fixed metal ceramic bridges was based on the material consisting of all the patients who were treated with fixed metal ceramic bridges by dental students at the Department of Prosthodontics and Stomatognathic Physiology during the years 1984 – 96 (Fig. 1). There were altogether 414 patients: 147 men (35 %) and 267 women (65 %), the age range was 23 - 81 years and mean age was 46.6 years. The patients were divided into five age groups: under 24 years, 25 - 34 years, 35 - 49 years, 50 - 64 years and over 65 years (according to Tervonen 1988a) (Paper I, Table 1). There was only one patient under 24 years of age, so she was included in the group of patients who were 25-34 years old and the group name was changed to under 34 years.

Data were collected from the patient files. Altogether 540 fixed bridges including 1374 abutments and 804 pontics were made. The pontics were selected for the evaluation because they describe the number of teeth extracted. The distribution of the pontics and the cantilever extension pontics of fixed bridges in dentition is shown in Paper I, Fig. 1. Three teeth groups which were most often replaced by fixed bridges were selected for analyses. The teeth groups were upper lateral incisors (teeth 12 and 22), upper first premolars (teeth 14 and 24) and lower first molars (teeth 36 and 46). The years 1984 - 96 were divided into three time series: 1984 - 87, 1988 - 92 and 1993 - 96. The number of pontics in each age group and in each time period is presented in Paper I, Table 2.

4.2.2 Paper II

The specific aim of the study was to evaluate the complications and primary failures related to fixed metal ceramic bridges during the years 1990 – 93. Altogether 61 patients (32 women, 28 men, mean age 49 years, range 28 – 73 years) were treated by dental students as patients with fixed metal ceramic bridges at the Department of Prosthetic Dentistry and Stomatognathic Physiology during the years 1990 – 93 (Fig. 1). Single crowns were not included in the study. Data concerning preprosthetic treatment, the preparation phase and the six-month follow-up examination after the completion of the treatment were collected from the patient files. Altogether 82 fixed bridges were made containing 221 abutments (including 47 cast dowel and cores) and 136 pontics (Paper II, Fig. 1 and Fig. 2).

4.2.3 Paper III

The influence of previous restoration of the tooth on prognosis of crowns with dowels was analysed in 111 single crowns which were made by dental students at the Department of Prosthodontics and Stomatognathic Physiology at the University of Oulu during the

years 1984-1996 (Fig. 1). All the crowns were made in the same technical laboratory. No abutments of the fixed bridges were included in this study. The crowns were selected from 945 single crowns with dowels using criteria of previous restoration (Paper III, Fig. 1). Only one single crown per patient was included in the study and if more than one crown was prepared for one patient, randomisation was used for statistical analyses. Patient age and sex distribution is shown in Paper III, Table 1.

Two kinds of previous restorations were studied: 83 composite resins with parallel-sided cemented screw post and 28 one-piece dowel crowns (Paper III, Fig. 1). Data concerning preprosthetic treatment, the preparation phase, the six-month follow-up examination after the completion of the treatment and the complications and other procedures after the prosthetic treatment were collected from patient files during the year 1998. The complications recorded were root fractures, losses of cement retention and extractions for periodontal or carious reasons. The mean follow-up period was 78 months (6 to 163 months, 1 to 13 years).

4.2.4 Paper IV

The material of the 10-year follow-up study of fixed metal ceramic prostheses consisted of 60 patients (30 women, 30 men) who were treated at the Department of Prosthetic Dentistry and Stomatognathic Physiology in 1984- 85 (Fig. 1). All the patients were sent an invitation but only 30 attended the follow-up examination. Three patients replied that they could not attend and 27 did not contact us at all. The cases examined clinically consisted of 16 women (mean age 39, range 23 – 62 years) and 14 men (mean age 44, range 26 – 65 years) (Paper IV, Table I). Data regarding treatment procedures were collected from the patient files.

The clinical examinations were done by the author. At the beginning of the examination anamnestic data and the patients' subjective opinions about their fixed prostheses were asked. Detailed questions are presented in Appendix 2. In the clinical part of the examination the condition of the oral mucosa, periodontal condition (probing calculus and pockets, gingival bleeding), caries, location of the crown margins relative to the gingival margins and mobility of the abutments were evaluated. The colour, surface structure and shape of the crowns and abutments were also examined and classified as acceptable or unacceptable. The clinical examination was finished with intra-oral radiographs on 29 of the patients. One patient refused due to pregnancy.

4.2.5 Paper V

Altogether 540 bridges were fabricated for 414 patients by undergraduate students at the Department of Prosthetic Dentistry and Stomatognathic Physiology in 1984 - 1996 (Fig. 1). For evaluation of the survival and late complications related to fixed metal ceramic prostheses two examination groups were selected for this study on the basis of the length of the fixed bridge. All the patients who had a fixed bridge consisting of 5 or more units (53 patients) were selected to the group of extensive fixed bridges. Twice the

number of patients (106 patients) were selected at random to the group of short fixed bridges (3 or 4 units) than to the group of extensive ones. Two patients had died and seven patients had moved out of the district so an invitation to the clinical examination was sent to 150 patients altogether.

132 patients attended the clinical examination (88 % of the patients invited). Three patients replied that they could not attend and 15 patients did not contact us at all. There were 48 men (36 %) and 84 women (64 %), the age range was 39 – 82 years, the mean age being 56.8 years. The distribution of the study group is shown in Paper V, Table 1. The patients had a total of 204 fixed bridges made at the Institute of Dentistry, fixed bridges made elsewhere were excluded from the study. From the patients 60 % (79 patients) had only one fixed bridge, 28 % (37 patients) had two fixed bridges, 10 % (13 patients) had three fixed bridges and 2 % (3 patients) had four fixed bridges. The mean follow-up period was 91 months (27 to 181 months).

The same formula as in Paper IV was used in the clinical examination. All examinations were performed by the author. At the beginning of the examination the subjects were asked if there had been pain or other sensations around the bridges or if any complications had occurred (Appendix 2). In the clinical part of the examination the occlusion, the condition of oral mucosa, periodontal condition (probing calculus and pockets, gingival bleeding), caries and mobility of the abutments were evaluated. The colour, surface structure and shape of the bridges were also examined. The clinical examination was concluded with intra-oral radiographs of the abutments. The patient files were examined to get further information concerning the complications which had been treated in our clinic.

The salivary findings of the patients at baseline were registered from the patients files. The flow rate of stimulated saliva had been measured for 5 minutes, the mutans streptococci (SM) and the lactobacilli (LB) score had been determined using commercial techniques: a strip mutans test (Alaluusua *et al.* 1984) Dentocult SM® and a dipslide test (Larmas 1975) Dentocult LB® (Orion Diagnostica, Espoo, Finland).

The scores of the salivary tests were divided into two categories indicating either a high or low level for the caries-related factor. Cut-off points were selected according to Larmas (1987) and Vehkalahti *et al.* (1996): a flow rate of stimulated saliva of 1.0 ml/min or less, an SM score of 2 or 3 (more than 10^5 CFU/ml, CFU means colony forming units) and an LB score of 5 or 6 (more than 10^5 CFU/ml) indicated a high risk of caries.

Late complications related to the fixed metal ceramic bridge prostheses were divided into four categories (Paper V, Table 2). Group 1 included minor complications, i.e. porcelain fractures and minor caries lesions or fillings. Group 2 included moderate complications which can still be repaired at the dental office, i.e. root canal therapy through the bridge (result of caries, inflammation of the pulp or periapical lesion seen in the radiograph) or re-cementation of the whole bridge. Group 3 included severe complications that usually require the use of a dental laboratory, i.e. root canal therapy which requires removing of the bridge and preparing a separate dowel, either prefabricated or custom-made. Group 3 also included re-soldering of the bridge and situations in which the abutment tooth had to be extracted in the middle of the bridge without causing any harm to the function of the bridge. Group 4 included extensive complications, i.e. the bridge had been cut or totally removed because of extraction of the abutment tooth.

4.3 Statistical methods

In Paper I simple graphical methods were used to clear the trends between the age groups and the time periods studied. There were only six fixed bridges in the age group of under 34 years old during the years 1993 – 96, and only two fixed bridges during the years 1984 – 87 and 14 during the years 1988 – 92 in the age group of over 65 years. The low numbers would have caused a statistical error and they were excluded from analysis.

In Paper III a survival analysis of Kaplan-Meier was used in analysis of the survival rate to compensate a variation in follow-up times of single metal ceramic crowns. Only one single crown of each patient was included in the study; if two or more crowns were prepared, one crown was selected randomly to get independent samples. The survival of the single crowns was based on absence of the recorded complications. The differences in the survival between the groups studied were analysed with Log Rank test by the SPSS-program (version 7.1).

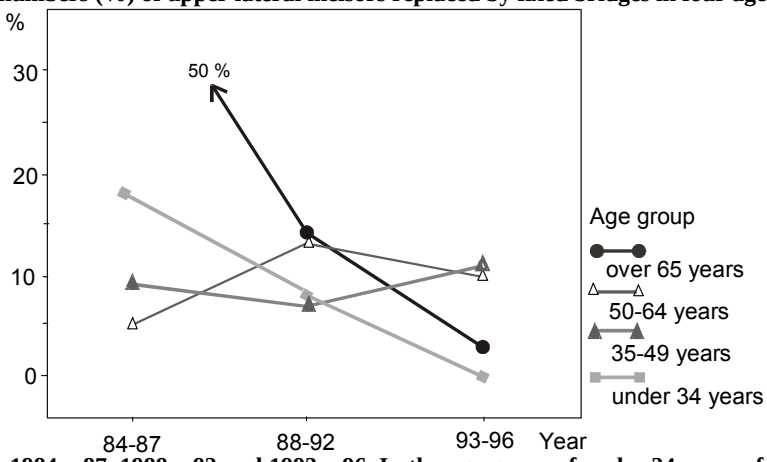
In Paper V the survival analysis of Kaplan-Meier was performed in calculating the survival rate. Analyses were performed using a patient and a mouth as a statistical unit because in that way the samples were independent. All the fixed bridges in the mouth which were performed at the Institute of Dentistry were taken into account in order to find every complication. In addition, the Cox regression models were performed to covariate the variables used. In this analysis a fixed bridge was used as a statistical unit. The survival of the fixed bridges was counted from the day the fixed bridge was cemented in the mouth to the day of any complication, or if no complications occurred, to the day of the clinical examination. Mean survivals, Log Rank scores and Cox regression analyses were performed by using the SPSS-program (version 7.1), the variables used were patient's age, length of the bridge, flow rate of saliva, scores of salivary tests for mutans streptococci (SM) and lactobacilli (LB), and the number of endodontically treated teeth. Only severe and extensive complications, i.e. groups 3 and 4 (Paper V, Table 2) were selected for the final analysis. The overall survival percent was counted at the point of 10 years, because there were few fixed bridges (38 fixed bridges) that were made over 10 years ago and therefore the survival rate counted after 10 years may not be reliable.

5 Results

5.1 Treatment need

In the youngest age group the upper lateral incisors were most often replaced by fixed bridges in the years 1984 – 87 (19 %). Afterwards fewer upper lateral incisors were replaced in that age group (Fig. 5). In the groups of 35 – 49 years and 50 – 64 years of age a slight increase was seen in the numbers of pontics (from 8 % to 11 % and from 5 % to 11 %, respectively) and in 1993 – 96 the numbers were highest when compared to other groups. In the oldest age group the number of upper lateral incisors as pontics in the years 1993 – 96 was only 3 %.

Fig. 5. The numbers (%) of upper lateral incisors replaced by fixed bridges in four age groups



in the years 1984 – 87, 1988 – 92 and 1993 – 96. In the age group of under 34 years of age the number of 1993 – 96 and in the age group of over 65 years of age the numbers of 1984 – 87 and 1988 – 92 were not analysed due to a low number of cases.

In the youngest age group 15 % of all pontics in the years 1984 - 87 were upper first premolars and the proportion decreased after that (Fig. 6). In the groups of 35 – 49 years

and 50 – 64 years of age the numbers were around 20 % during the whole time period, although a slight decrease can be seen (22 % to 17 % and 23 % to 18 %, respectively). In the oldest age group the upper first premolars were replaced in 22 % of all fixed bridges in the years 1993 - 96, which was the highest number when compared to other groups.

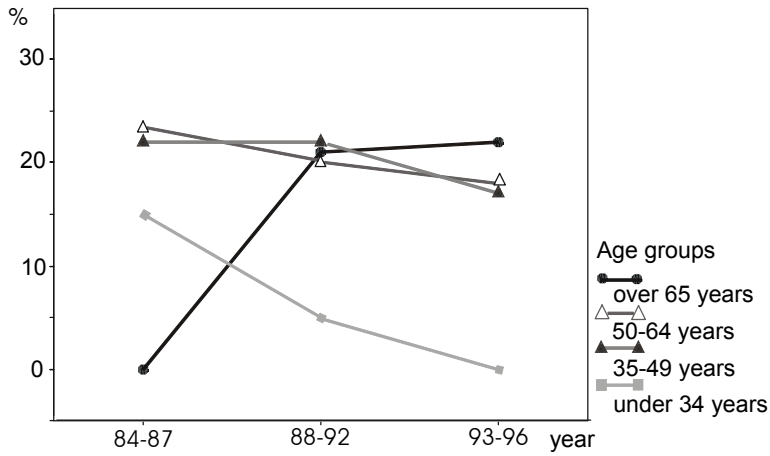


Fig. 6. The numbers (%) of upper first premolars replaced by fixed bridges in four age groups in years 1984 - 87, 1988 - 92 and 1993 - 96. In the age group of under 34 years of age the number of 1993 – 96 and in the age group of over 65 years of age the numbers of 1984 – 87 and 1988 – 92 were not analysed due to a low number of cases.

In the age group of under 34 years old the number of lower first molars was 13 % in the years 1984 – 87 and 18 % in the years 1988 – 92 (Fig. 7). In the age group of 35 – 49 years of age the proportion of lower first molars decreased slightly during the years 1984 – 96 (from 21 % to 19 %). In 1984 – 87 the lower first molars were often replaced by fixed bridges in the age group of 50 – 64 years of age, but the relative proportion decreased after that (from 25 % to 12 %), being only 7 % in the years 1988 – 92. In the oldest age group the number was 16 % in the years 1993 – 96.

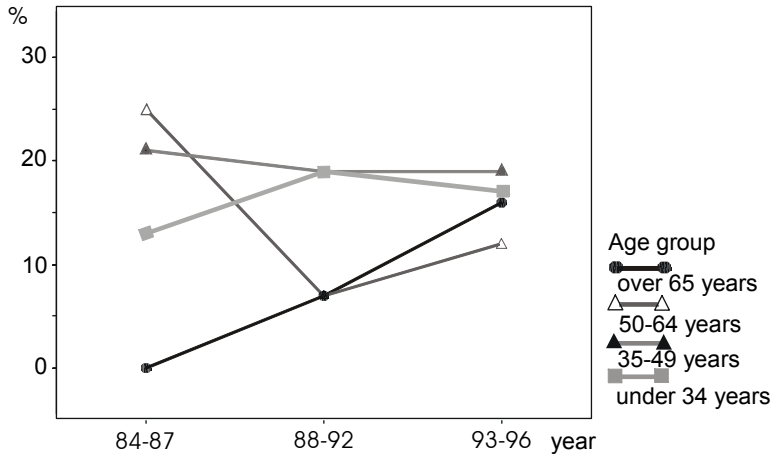


Fig. 7. The numbers (%) of lower first molars replaced by fixed bridges in four age groups in years 1984 - 87, 1988 - 1992 and 1993 - 96. In the age group of under 34 years of age the number of 1993 – 96 and in the age group of over 65 years of age the numbers of 1984 – 87 and 1988 – 92 were not analysed due to a low number of cases.

5.2 Primary complications

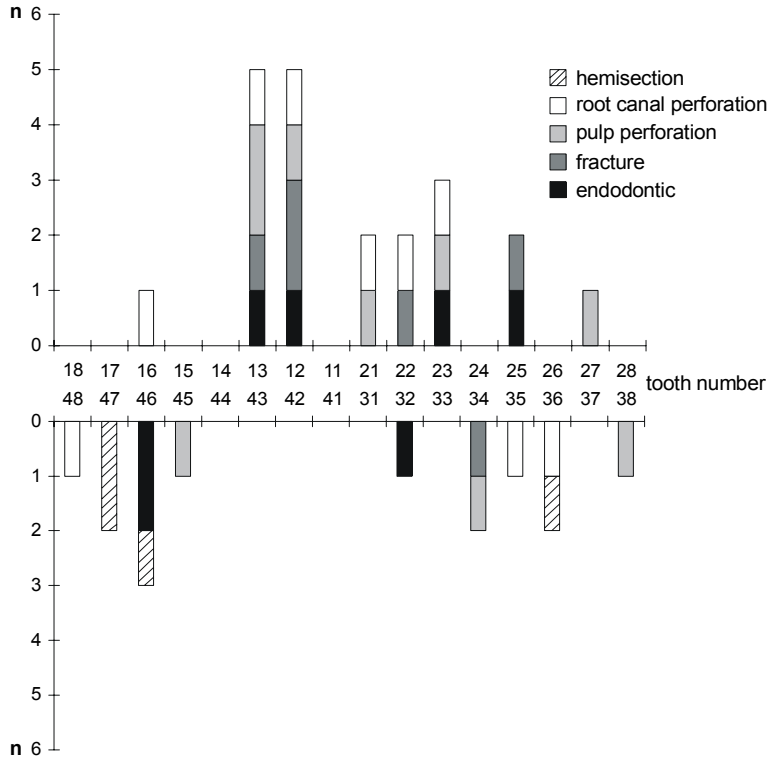
In preprosthetic endodontic treatment of the fixed bridges in 1990 - 93 one left lateral incisor was extracted following root perforation (0,4 % of all abutments) (Paper II) (Table 4). When analysing the whole material (1374 abutments), there were 11 perforations (0.8 % of abutments) recorded in the patient files during the preprosthetic endodontic treatment, of which eight perforations caused extraction of the planned abutment tooth, and in three cases hemisection of the lower molar was performed (Fig. 8).

Due to perforation of the root canal during the preparation for cast dowel and cores two planned abutment teeth (1 %) had to be extracted, and due to fracture in removing the old crown two planned abutment teeth (1 %) were extracted in 1990 – 93 (Paper II) (Table 4). These two types of primary complications caused extraction of nine (0.6 %) and six planned abutment teeth (0.4 %) each (Table 4, Fig. 8). In preparation of the abutment teeth there were two pulp perforations in 1990 – 93 and nine pulp perforations in the entire material (Table 4, Fig. 8), of which calcium hydroxide therapy was successful in five cases and the teeth could be used as abutments, but in four cases of these endodontic treatment was carried out.

Table 4. The number of primary complications in preparation of the abutment teeth for fixed metal ceramic bridges in the years 1990 – 93 versus 1984 – 96.

Primary complication	Paper II (n=221)		whole material (n=1374)	
	n	%	n	%
Perforation in endodontic treatment	1	0.4	11	0.8
Perforation in root canal preparation	2	1	9	0.6
Tooth fracture in removing the old crown	2	1	6	0.4
Pulp perforation in preparation	2	1	9	0.6

Fig. 8. The location of the primary complications in dentition in the entire material.



Hemisection: hemisection was performed due to perforation in the preprosthetic endodontic treatment. Root canal perforation: a perforation during the preparation of the root canal. Pulp perforation: a pulp perforation in preparation of the abutment tooth. Fracture: tooth fracture when the old crown was removed. Endodontic: a perforation of the root canal during preprosthetic endodontic treatment of the planned abutment tooth.

The marginal fidelity of the metal frame work was not acceptable in four out of 82 fixed bridges (5 %) in 1990 - 93 (Paper II) (37 out of 543 fixed bridges (7 %) in the whole material) and the fixed bridges were re-soldered or re-made. The firing of the porcelain was repeated in four cases (5 %) for aesthetical reasons and in three cases (3 %) for

repairing of the porcelain work in 1990 – 93 (Paper II). The corresponding numbers of the fixed bridges in the entire material were 45 cases (8 %) and 38 cases (7 %).

Altogether 455 patients of 772 treated patients (58 %) attended the six-month follow-up examinations. 64 % of the patients had no objective or subjective complaints. Some gingivitis was found in 22 %, mild occlusal discrepancy in 9 % and sensitivity to gold in 4 % of the patients. The periodontal treatment and occlusal adjustment needed was performed.

5.3 The subjective findings of the patients

5.3.1 Subjective signs and symptoms

Subjective signs and symptoms of the patients were recorded in Papers IV and V. The most common subjective symptoms were gingival bleeding, root sensitivity in the cervical area and pain (Table 5). To a less degree there was sensitivity to cold and heat and mobility of the restorations. The prosthetic reconstructions were stated to have influenced speech by 20 % of the patients in the 10-year follow-up (Paper IV) and by 12 % of the patients in the clinical examination presented in Paper V. The effects reported were changes in the sound ‘s’ and observations that speaking was more comfortable after the prosthetic treatment. Generally the subjects were satisfied with their crowns and fixed bridges, and 93 % of the patients had no complaints about the aesthetics, colour, shape or glossy finish of the crowns and fixed bridges in either of the clinical examinations (Papers IV and V).

Table 5. Subjective signs and symptoms of the patients recorded in clinical examinations (Paper IV n= 30, Paper V n = 132).

Subjective signs and symptoms	Paper IV		Paper V	
	n	%	n	%
Cervical root sensitivity	5	17	7	5
Gingival bleeding	4	13	29	22
Pain	4	13	19	14
Sensitivity to cold	1	7	13	10
Sensitivity to heat	2	7	4	3
Mobility	2	3	7	5
More comfortable to speak	2	7	3	2
The sound ‘s’ had changed	4	13	13	10

5.3.2 Home care and dental treatment after the prosthetic treatment

In the 10-year follow-up examination (Paper IV) all the subjects reported that they used a toothbrush and toothpaste at least once a day, while in the clinical examination of Paper V two subjects reported that they do not brush their teeth every day. The use of dental floss, floss for the fixed bridges, interproximal brushes and tooth picks was irregular although patients were encouraged to use them. Patients reported problems in home care related to tight interproximal spaces (2 %) and difficulties in cleaning the most distal parts of the dentition (3 %) (Paper V).

The subjects had visited a dentist irregularly during the time period following the prosthetic treatment (Table 6). In the 10-year follow-up examination (Paper IV) 63 % of the subjects had visited a dentist only when necessary, while in the clinical examination of Paper V 40 % of the subjects had done so. For 7 % and 10 % of the patients, respectively, the examination was the first since the prosthetic treatment.

Table 6. Dental treatment of the patients treated with fixed metal ceramic prostheses after the prosthetic treatment.

Dental treatment	Paper IV		Paper V	
	n	%	n	%
More often than once a year	3	10	8	6
Once a year	6	20	58	44
Only if necessary	19	63	53	40
No visits	2	7	13	10
Total	30	100	132	100

5.4 The clinical and radiological findings

Minor occlusal discrepancies were found in 9 of the 132 subjects (7 %) in the clinical examination of Paper V. In the 10-year follow-up examination only subjective opinions concerning the function of the fixed bridges were evaluated. Oral mucosa was healthy in 40 % of the subjects in the 10-year follow-up examination (Paper IV). A mucosal change of the lichenoid type was found in 27 % and a chewing trauma in the cheek in 13 %. In the examination presented in Paper V healthy oral mucosa was found in 82 % of the subjects. Mucosal changes recorded were lichenoid lesion (10 %), nodule (4 %), amalgam tattoo (2 %) and erythematous lesion (2 %).

Bleeding on probing around the crowns and fixed bridges was found in 27 % of the subjects in the 10-year follow-up examination (Paper IV). In the examination presented in Paper V gingival bleeding was found in 48 % of abutments. Calculus was found in 24 % of abutments. Periodontal pockets (4 – 6 mm) were found in 12 % of the abutments or single crowns in the 10-year follow-up examination, and one fixed bridge was mobile because of a deterioration in general periodontal condition (Paper IV). In the

clinical examination of Paper V 12 % of the subjects had periodontal pockets over 4 mm deep; one fixed bridge was lost because of poor periodontal condition.

In cariological examination of the 10-year follow-up (Paper IV) none of the subjects had caries or fillings in abutments or in the crown margin area. In the clinical examination presented in Paper V caries was found in 4 % of all abutments (24 teeth). In five teeth (1 % of all abutments) the restoration was made in the crown margin area.

Radiological examination was performed on 29 of the subjects in the 10-year follow-up examination, one patient refused because of pregnancy. Apical periodontitis was found in teeth associated with crowns or abutments of fixed bridges in nine patients and marginal periodontitis in three patients (Paper IV, Table 4). In the clinical examination of Paper V altogether 130 patients were examined with intra-oral radiographs, two patients refused because of recent radiological examination. Apical periodontitis was found in 28 abutment teeth (5 %) and vertical of horizontal changes at the border of alveolar bone around 42 abutment teeth (7 %).

The marginal fidelity was unsatisfactory in four fixed bridges in the 10-year follow-up examination (Paper IV), whereas in the clinical examination of Paper V open retainer margins were found in 11 % of all abutments. Aesthetically the crowns and fixed bridges were satisfactory in both clinical examinations, and wear on both the crowns/abutments and the opposite contact teeth was slight. The contact between the porcelain and metal was faultless in all the restorations in the 10-year follow-up examination (Paper IV), whereas in 2 % of abutments and pontics in the clinical examination of Paper V a slight wear was seen in the contact area.

5.5 Late complications and survivals

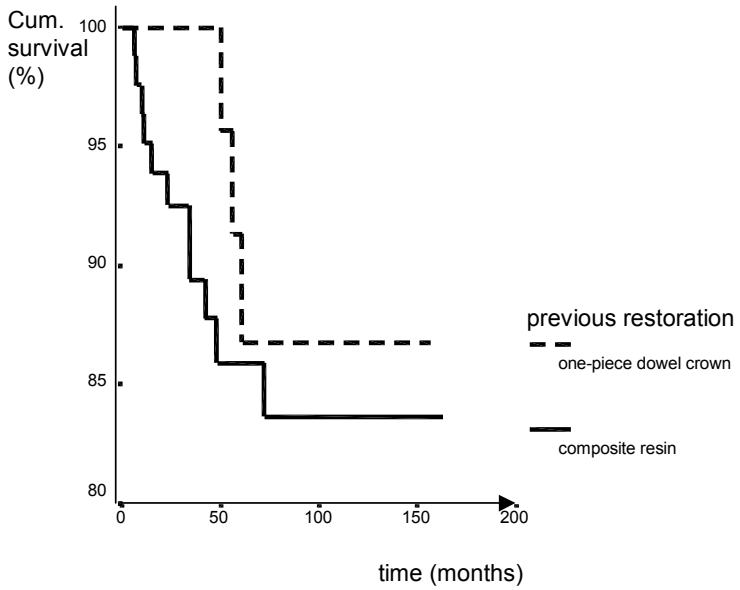
5.5.1 Single metal ceramic crowns

Late complications of 41 single metal ceramic crowns were evaluated clinically and using patient files in the 10-year follow-up study (Paper IV). There were 19 veneer crowns with a cast dowel and core (46 %), 11 one-piece dowel crowns (27 %) and 10 veneer crowns (27 %). Eight single crowns (19 %) were loosened and recemented before the follow-up examination and one single crown was recemented in the follow-up examination. In three single crowns (7 %) a porcelain fracture was observed. The survival rate of the single crowns was not counted.

The complications and survival of the 111 single crowns with dowels were analysed based on the effect of the previous restoration of the tooth (composite resin with a screw post versus one-piece dowel crown) (Paper III). There were altogether 14 complications in 111 single crowns, which included eight root fractures, four losses of cementation and one extraction for periodontal and one for carious reasons (Paper III, Table 2). There were six root fractures in 83 crowns with composite resin with screw post as a previous restoration, two of the root fractures were observed only 6 months after completion of the treatment (Paper III, Table 3). The root fractures were in three upper lateral incisors and in three upper first premolars. Other complications were losses of cement retention (four

cases, all crowns were recemented) and one tooth extraction for carious reasons. In 28 one-piece dowel crowns as a previous restoration there were two root fractures (Paper III, Table 2), both in the upper lateral incisors. One tooth was extracted for periodontal reasons. The cumulative survival was 87 % for one-piece dowel crowns and 84 % for composite resins with screw posts as a previous restoration after 72 months (Fig. 9). No statistically significant difference was found between the restorations (p=0.52).

Fig. 9. Survival analysis (Kaplan-Meier) of the single metal ceramic crowns distributed by previous restoration of the tooth.



5.5.2 Fixed metal ceramic bridges

In 24 fixed bridges in the 10-year follow-up examination (Paper IV) there were three porcelain fractures (12 %), three fixed bridges (12 %) were recemented and endodontic treatment was performed through one retainer. In two fixed bridges (8 %) with cantilever extensions soldering had been broken (after one and six years) and the cantilever extensions had been cut away. One fixed bridge (4 %) was re-soldered after eight years.

In the clinical examination presented in Paper V there were altogether 49 complications in 204 fixed bridges, of which 18 were minor, 12 moderate, eight severe and 11 extensive complications (Table 7). Minor complications (Group 1) were mostly porcelain fractures which did not need to be repaired (14 cases). In Group 2 (moderate complications) the most common involvement of complication was periapical inflammation (seven teeth). In severe complications (Group 3) four separate cast dowel and cores were added into fixed bridges and two fixed bridges were re-soldered. Two

abutment teeth were extracted within the fixed bridge, but the function was not disturbed and the fixed bridge could be saved. Extensive complications (Group 4) included four cuttings of the fixed bridge because of extraction of the abutment tooth. Seven fixed bridges were totally removed because of five root fractures of abutment teeth and two remakes of fixed bridges because of caries or periodontal involvement in abutment teeth.

On the basis of severe complications (Groups 3 and 4) the overall survival of fixed bridges after ten years was 84 % (Fig. 10). When analysing the variables influencing complications the most important factor was the length of the fixed bridge: long fixed bridges had a lower survival than shorter ones (p=0.04) (Paper V, Table 3). Low secretion of stimulated saliva (< 1 ml/min) measured at the baseline of the prosthetic treatment also decreased the survival of fixed bridges (p=0.12). The survival of the fixed bridges was likewise reduced by high scores of lactobacilli and mutans streptococci (p=0.07 and p=0.20, respectively). If there were more than three cast dowels and cores in the fixed bridges of the patient, the survival was lower than if there were 0-2 cast dowels and cores (p=0.09). The age of the patient did not influence the survival.

Fig. 10. Survival analysis (Kaplan Meier) of the fixed metal ceramic bridges.

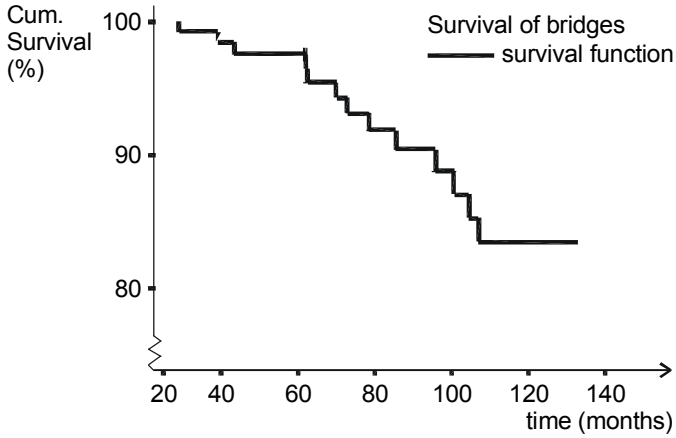


Table 7. Complications of the short and long fixed metal ceramic bridge prostheses divided into four groups based on severity of the complications.

Complication	Short fixed bridges (3 – 4 units)	Long fixed bridges (5 - 11 units)	Total
Minor complications (Group 1)			
Porcelain fractures	9	5	14
Minor caries lesions	2	1	3
Minor fillings in the crown margin area	0	1	1
Total	11	7	18
Moderate complications (Group 2)			
Root canal therapy through the fixed bridge	2	0	2
Periapical inflammation	5	2	7
Re-cementation of the fixed bridge	2	1	3
Total	9	3	12
Severe complications (Group 3)			
Separate dowel added to a fixed bridge (either prefabricated or custom-made)	0	4	4
Re-soldering of the fixed bridge	1	1	2
Extraction of the abutment tooth without any harm to the function of the fixed bridge	1	1	2
Total	2	6	8
Extensive complications (Group 4)			
Extraction of the abutment, fixed bridge had to be cut	2	2	4
Total removal of the fixed bridge	6	1	7
Total	8	3	11
All complications	30	19	49

As a comparison, statistical models using the Cox proportional hazards regression model were also fitted. The fixed bridges were used as statistical units in spite of the presence of the same person repeatedly in the data. There were only 19 severe complications (Groups 3 and 4) in the data set consisting of 204 fixed bridges, and detailed statistical modelling with several simultaneous explanatory variables was therefore difficult. Two most significant variables were used to predict the survival of fixed bridges (Table 8). The results are consistent with the previous results obtained by the Kaplan-Meier method (Paper V, Table 3) and although the p-values of the regression coefficients are relatively high, the statistical model shown here may be explanatory (Table 8). It can be seen that the risk for complication is 2.7 times higher if the patient has a low secretion of saliva (a flow rate of stimulated saliva of 1.0 ml/min or less) than if the secretion of saliva is within normal limits. Furthermore, the model suggests that the risk for complication in fixed

bridges increases 1.3 times per unit, which concludes that the long fixed bridges have a lower survival than the shorter ones.

Table 8. The results of the Cox regression model in analysing the variables influencing the complications related to the fixed metal ceramic bridge prostheses.

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	p-Value	Risk Ratio
Secretion of saliva [1]	1	0.990	0.567	3.050	0.081	2.691
Length of the bridge [2]	1	0.254	0.147	3.009	0.083	1.290

1) Stimulated saliva classified into two groups. Low secretion of saliva: 1.0 ml/min or less, normal secretion of saliva >1,1 ml/min
2) Length of the fixed bridge (units)

6 Discussion

6.1 Material and methods

The material of this study consists of 772 patients who were treated with metal ceramic fixed prostheses by undergraduate students during the years 1984 – 1996. Due to the large size of the material it can essentially reflect the prosthetic treatment with fixed metal ceramic prostheses. The distribution of pontics and single crowns also matches the studies performed in general practice (Silness 1970, Berge & Silness 1990, Eckerbom *et al.*1991) and also at University Clinics (Valderhaug & Karlsen 1976, Silness & Berge 1990).

In Sweden it has been possible to introduce several studies on the basis of the National Insurance System, which has preserved the information concerning prosthetic treatment since 1975. In Finland no such files are available, and it is also difficult to obtain suitable data on dental treatment from health centres or private practices since their records and notes are inconsistent. The patient records of the Institute of Dentistry provide an extensive, homogenous material to be evaluated, because notes of the treatment phases are strictly registered phase by phase and supervisors have controlled the treatment phases of the undergraduate students according to uniform criteria.

Although the material is large, difficulties related to the nature of the clinical study restricted the analyses in some parts of the study. In Paper I the number of fixed bridges in the age group of under 34 years old in 1993 - 96 and in the age group of over 65 years old in 1984 - 87 and in 1988 - 92 was so low that it could have caused a statistical error, and they were therefore excluded from the analysis (Paper I, Table 2). The information of long-term clinical findings and complications is restricted because it depends on the patients' interest to participate in follow-up examinations. In addition, when the only source of information is patient files, information of the patients who failed to show up is lacking. Although a six-month follow-up examination was included in the prosthetic treatment, only 58 % of the patients took advantage of these examinations, and in the 10-year follow-up examination (Paper IV) only 50 % of the 60 patients invited attended the clinical examination. On the other hand, in the clinical examination presented in Paper V as many as 83 % of the 132 invited patients attended the examination. Ten years is quite a

long time and patients could have moved out of the district or maybe they could not be reached for some other reason, which might explain the low participation in the 10-year follow-up. Despite the eagerness to participate in Paper V, the survival percent of the fixed bridges had to be counted at 10 years, because there was such a low number of patients treated more than 10 years before the examination that counting of the survival for the rest of the fixed bridges after 10 years would not have been reliable.

6.2 Treatment need

6.2.1 Reasons for treatment with fixed prostheses

The treatment decision with single metal ceramic crowns has most often been preceded by a large restoration of the tooth (44 %) or fractured restoration or tooth (16 %) (Table 2). The replacement of ordinary amalgam or composite resin restoration with a single crown calls for information and motivation of the patient provided by a dentist. Dentists should be more prepared to offer durable single crowns, or cast inlay and onlay restorations, in cases where the conventional restoration is not the best solution, because patients are not necessarily aware of all treatment alternatives. In addition, the increasing incidence of allergies caused by composite materials could influence treatment planning. Although according to this material only four single crowns were prepared because of allergy, the incidence of allergies might be higher in the future.

In treatment with fixed bridges frequent reasons were extractions of the tooth/teeth either formerly or during the dental treatment at the Institute of Dentistry. To a less degree a reason for the treatment was replacement of removable prosthesis, renewal of the fixed bridges. The results were similar to the study of Ödman & Karlsson (1988), in which the most frequent reason for the treatment with a fixed bridge was patients' wish to fill gaps, other reasons were periodontitis, aesthetics and difficulty in chewing. Although a missing tooth does not subjectively require replacement with a prosthesis in all cases (Björn & Öwall 1979, Tervonen 1988b), patients need information of the treatment alternatives including fixed bridges. Implants must also be kept in mind in suitable cases.

6.2.2 Treatment need according to pontics in different age groups

The treatment need was evaluated here according to missing teeth, i.e. pontics, in the age groups of under 34 years, 35 – 49 years, 50 – 64 years and over 65 years of age in 1984 – 87, 1988 – 92 and 1993 – 96, providing a treatment need from a new point of view. When comparing the whole time period 1984 - 96 at the Institute of Dentistry, it can be seen that the median age of the patient needing prosthetic treatment has risen during the years. While in 1984 - 87 patients under 34 years of age made up a large part of the patients, in the years 1993 - 96 only few patients under 34 years of age were seeking prosthetic treatment at the Institute of Dentistry (Paper I, Table 2). These results support the results of earlier studies from the Oulu area recorded by Tervonen (1988a) and Hartikainen

(1994) that younger age groups have less missing teeth than was earlier the case in the northern part of Finland as well. The main reason is probably the public health care system that has taken good care of young people's teeth, so that they do not need large restorations like single crowns or fixed bridges. Furthermore, the Social Insurance system provides financial support for patients born later than 1945 when they have their teeth treated in private dental office, although prosthetic treatment is excluded from the system. Another reason for the diminished number of fixed bridges in younger age groups is the fact that if a single tooth has to be extracted (injury etc.), a dental implant is most often a first choice, because the adjacent teeth are usually intact or have only a small restoration.

On the contrary, the proportion of elderly people with more remaining teeth is increasing, as is their need for demanding oral rehabilitation. In the age group of over 65 years old only two teeth were replaced in the upper jaw between the years 1984 - 87, but in 1993 - 96 32 teeth were replaced in the same age group (Paper I, Table 2). The increasing demands of the elderly were also observed by Ranta (1987) and Hartikainen (1994). Fixed prosthesis is a favourable restorative treatment alternative also in older age groups because age does not increase the risk for complications (Paper V). This was also noted by Glantz & Nilner (1993).

When evaluating the numbers of fixed bridges among the different age groups a clear shift could be seen: most fixed bridges were prepared for the age group 35 - 49 in the years 1988 - 92 and 1993 - 96 (Paper I, Table 2). It could therefore be stated that treatment with fixed bridges has started on a larger scale with people born in 1948 - 55. A major reason for their improved dental health and change of prosthetic treatment from removable/complete dentures to fixed prostheses is the fact that when they were adolescents in 1972 the law ordered the public health system to arrange dental care and public health centres were founded. At that time children were also taken into systematic treatment and more dentists were needed also in the peripheral parts of Finland, and adults were also given access to dental treatment on a larger scale.

6.3 Distribution of the fixed metal ceramic prostheses

6.3.1 Distribution of the single crowns

Most of the metal ceramic single crowns were prepared in the anterior segment of the upper jaw (Fig. 2). This could be assumed to be directly related to aesthetical reasons. The same results were also obtained by Silness (1970) in Bergen, Norway, Valderhaug & Karlsen (1976) in Oslo, Norway, Eckerbom *et al.* (1991) in Sweden and Fyffe (1992) in Scotland, but in the study of Leempoel *et al.* (1987) in the Netherlands most crowns were constructed on first molars. Berge and Silness (1990) analysed the distribution of the single crowns performed at the University Clinic in Bergen, Norway, and found that the most often crowned teeth in the upper jaw were, besides the incisors, the premolars. In lower jaw single crowns are most often prepared in the premolars (Fig. 2), which has also been seen in other studies (Silness 1970, Valderhaug & Karlsen 1976, Berge & Silness 1990, Silness and Berge 1990). The reason for this is most probably the fact that lower

premolars are commonly used as abutments for removable prostheses. On the other hand, lower first molars were even more often prepared for single crowns than lower premolars in the study of Berge & Silness (1990), in which single crowns produced by commercial dental laboratories in Norway were analysed.

6.3.2 Distribution of the fixed bridges

More fixed bridges were prepared for women than for men and more often in the upper jaw than in the lower law (Paper I, Table 1 and Fig. 1). These facts support the results of other studies (Valderhaug & Karlsen 1976; Björn & Öwall 1979, Silness & Berge 1990, Eckerbom *et al.* 1991). More premolars and molars than incisors were replaced with fixed bridges in both jaws in our material (Paper I, Fig. I), and this differs from the studies of Björn & Öwall (1979) and Liedberg *et al.* (1991) in Sweden, in which most of the fixed bridges were in the upper anterior segment.

The most often replaced tooth in our material was the upper first premolar (Paper I, Fig. 1), seen also in other studies (Valderhaug & Karlsen 1976, Silness 1970, Björn & Öwall 1979, Silness & Berge 1990, Berge & Silness 1990, Eckerbom *et al.* 1991). Every fifth pontic was upper first premolar in the age groups of 35 - 49 years old and 50 - 64 years old during the whole time period 1984 – 1996, and when the number of fixed bridges increased in the age group of over 65 years old in 1993 – 96, the upper first premolar also increased its quantity up to 22 % (Paper I, Fig. 3). The reasons for extractions of upper first premolars could be related, besides to the complicated root anatomy of this tooth, also to occlusal factors which may predispose to the loss of the maxillary first premolar (Kirveskari & Alanen 1985). And from a subjective point of view, the upper first premolar is aesthetically more important than the teeth posterior to it, and extraction could therefore lead more easily to replacing it with a fixed bridge.

Perhaps a great deal of attention should be paid to the early strong repairing of the upper first premolar during restorative dental treatment. It seems that even a single crown would not be a overreaction with this tooth in some critical cases, and it should be kept in mind that inlay and onlay restorations are also alternatives for the conventional composite resin restorations. When caries penetrates to the dentin and the restoration or, first of all, endodontic treatment has to be carried out, the major part of the clinical crown and important supporting dentin over the narrow two-root complex in alveolar bone is lost, and the risk for root fractures increases, especially with crowns with dowels (Paper III). Although a single crown could support the remaining tooth, the treatment planning should be made with special care. There should be enough dentin in the clinical crown so that the preparation margin can be extended 2 mm apical to the junction of the core and the tooth (ferrule), because this has been shown to decrease significantly the risk for root fractures (Sorensen & Engelman 1990, Milot & Stein 1992, Morgano & Brackett 1999).

The lower first molars were also often used as pontics (Paper I, Fig. 1). These teeth are usually the first teeth which have to be restored and there are often large restorations in the lower first molars, or they may have been extracted. In the patients under 34 years old the lower first molars were in 1993-96 the only teeth that had to be replaced with fixed bridge (Paper I, Fig. 4). Less caries and fewer restorations in the molars than before are

found nowadays due to systematic dental treatment and preventive procedures (Raitio *et al.* 1999).

6.4 Materials used in fixed metal ceramic prosthodontics

This study included fixed metal ceramic prostheses and the long term results were positive (Papers IV and V). Although the follow-up studies introduced in the literature include in most cases more acrylic resin veneer than metal ceramic restorations, the metal ceramic ones gave good results also in those studies (Palmqvist & Swartz 1993). In this study technical complications related to ceramic veneers were most often only small porcelain fractures (Paper V, Table 2), which did not need repairing in most of the cases. In fact, the troublesome disadvantage of the porcelain veneer is that the repair of porcelain fractures is difficult. In repair work the mechanical alteration of a porcelain surface has been shown to be more important than agents that promote chemical bonding of composite resin to porcelain (Thurmond *et al.* 1994).

In prosthetic treatment many new core materials, dowels and dental cements have emerged during the years. Some of them have been widely used, some of them have been only in experimental use at the Institute of Dentistry. In the case of many materials the results of studies in literature are incoherent and long-term clinical follow-ups are lacking. That is why the choice of materials is based on tradition and generally accepted knowledge in fixed prosthodontics at the Institutes of Dentistry, especially in the education of undergraduate students.

If a dowel was needed, the conventional cast dowel and core was chosen in most of the cases in this material. Even if the individually cast dowel may be better than prefabricated ones (Gluskin *et al.* 1995), it has been presented that rigid cast dowels cause more root fractures than recently introduced elastic carbon fibre posts (Isidor *et al.* 1996, Sidoli *et al.* 1997). In this study no carbon fibre posts were used and no comparison can be made, but a root fracture of abutment tooth was in five cases out of 11 extensive complications the reason for failure of a fixed bridge (Paper V). Therefore, in specific teeth which are more prone to root fractures than other teeth, i.e. upper lateral incisors, upper first premolars (Paper III) and distal end abutment teeth (Karlsson 1986, Palmqvist & Swartz 1993), the choice of the post should be an important part of the treatment planning. However, the elasticity of carbon fibre posts can cause problems in the bond between the post and the adhesive dental resins (Love & Burton 1996, Purton & Payne 1996, Sidoli *et al.* 1997, O'Keefe *et al.* 2000), and compressive strength of the carbon fibre posts has also been shown to be inferior when compared to metallic posts (Sidoli *et al.* 1997). Despite the disadvantages, long-term results of the carbon fibre post have been promising (Fredriksson *et al.* 1998).

In cementation of single metal ceramic crowns and fixed bridges zinc phosphate cement has been clearly the most often used cement (77 % of both single crowns and fixed bridges). Repeated good long-term results in the literature (O'Brien 1997) and positive clinical results in this study as well (Papers IV and V) encourage the use of zinc phosphate cement further in the future. Newer resin cements have their place, based on their advantages over zinc phosphate cement, i.e. bonding to tooth surfaces and low

solubility to oral fluids (O'Brien 1997, Yoshida *et al.* 1998), but their position is impaired by possible biological effects (O'Brien 1997).

Occasional allergies for gold alloy (McKenna *et al.* 1995) have accelerated the improvement of new, inert materials for fixed prosthodontics. Titanium is a promising, biocompatible alloy which has been used in single crowns for a decade, and clinical follow-ups of single crowns and fixed bridges have been introduced (Bergman *et al.* 1990, Smedberg *et al.* 1998). The marginal adaptation of the titanium crowns is good (Karlsson 1993), but there are problems related to the firing of dental porcelain to titanium, and there is a risk for porcelain fractures out of the alloy (Könönen & Kivilahti 1994, Nilson *et al.* 1994). To solve this problem, ceramics with a coefficient of thermal expansion adjusted to titanium and a firing temperature low enough have been invented (Kaus *et al.* 1996), and the bond strengths in mechanical studies have been equal to porcelain fused to noble metal alloys (Persson & Bergman 1996). Long-term clinical follow-ups are also promising (Walter *et al.* 1999), although suspicions have arisen about the surface and colour stability of low-fusing ceramics in the long run (Bergman *et al.* 1999).

6.5 Primary complications

The primary complications that occurred in the prosthetic treatment performed by undergraduate students were only occasional. This could be assumed to be related to the control of every treatment phase. The results show that primary complications can be predicted to occur more often during the endodontic treatment of abutment teeth than during the preparation phase (Table 4). Therefore, although the primary endodontic treatment is based on specific diagnosis, maybe greater attention is called for when re-treatment of root-filled abutment teeth is considered. It must be kept in mind in evaluation of the root fillings of the planned abutment teeth that root fillings ending more than 2 mm of the apex have a significantly lower frequency of periapical lesions than root fillings ending within 2 mm of the apex (Ödesjö *et al.* 1990). Secondly, according to a study of Sjögren *et al.* (1990), only 62 % of all of the periapical lesions present in previously examined root-filled teeth healed after re-treatment. On the other hand, it has also been noted that in abutments which are endodontically treated after cementation through retainers there is a higher risk for retainer or abutment fracture than in those root-treated beforehand (Reuter & Brose 1984).

Primary complications also occurred commonly during the preparation of the root canals for a dowel (Paper II). This was also found in the evaluation of prosthetic claims in Sweden, where seven out of 12 reports concerned a root perforation of the prepared tooth (Öwall *et al.* 1992). To avoid these common complications a solution may be found in selecting a suitable dowel for the tooth, and a suitable drill for the preparation. It must be kept in mind that there are several types of dowels at hand nowadays, and in treatment planning great attention should be given to the anatomy of the tooth and to the choice of the most safe dowel in that situation.

Root canal perforations and pulp perforations of the abutment teeth during the preparation phase can be assumed to be caused to some extent by the lack of experience

of the dental students. Demands for the necessary parallelism of the abutment teeth, especially in long fixed bridges, may be too difficult for the students to perform and complications of this kind are possible. However, the same problem has been discussed in a study concerning the relationship between failure and design in conventional bridgework in general dental practice (Foster 1991).

The six-month follow-up examinations were used here to find primary complications related to the prosthetic treatment and to allow patients to report their signs and symptoms. Lindquist & Karlsson (1998) also prefer the early control of the treatment, and they stated that the failures appear and are much more frequent in the beginning of the life-span of a fixed prosthesis based on improper material dimensioning, misdiagnosed/improperly used abutments and factors related to the clinical situation. The six-month follow-up may therefore not be long enough and a later systemic follow-up examination is needed, for example after one year, especially in the case of long fixed bridges.

6.6 Subjective signs and symptoms

The patients were satisfied with the treatment, the only comments discussed with the patients during the follow-up examinations concerned the long duration of the treatment performed by the dental students. Ödman & Karlsson (1988) interviewed patients treated in private practice and in a dental school about their experiences of the treatment, and they also concluded that the opinions were similar in both groups, and the patients were satisfied with the treatment.

The most common problems reported by patients were root sensitivity in the cervical area, gingival bleeding, pain and influence on speech (Table 5). The patients had only few complaints about home care and hygiene with the fixed prostheses. One problem was bleeding under the pontics, which may be due to tight contact between the pontic and the mucosa, or simply negligent home care. Similar symptoms were also reported in the studies of Ödman & Karlsson (1988) and Yi *et al.* (1996), in which patients complained about sensitive root surfaces, hygiene and phonetics. Some patients also reported discrepancies between the fixed bridge and their own previous teeth and difficulties in interproximal tooth-cleaning (Ödman & Karlsson 1988). Especially the complicated bridgework may be more difficult for the patient to clean (Foster 1991).

The prosthetic treatment included a six-month follow-up for every patient, but after that no regular recall system is available at our Institute of Dentistry. The patients are naturally advised to seek dental treatment. Maybe the long treatment period had influenced the patients' willingness to visit a dentist after the prosthetic treatment, because in the 10-year follow-up examination (Paper IV) 63 % of the subjects who attended had visited a dentist only when necessary, and for 7 % of the patients the examination was the first after completion of the prosthetic treatment (Table 6). In the clinical examination presented in Paper V the corresponding numbers were 40 % and 10 %. However, as Karlsson (1989) also emphasized, regular dental treatment is very important in decreasing complications, such as the most common one, caries.

6.7 Clinical and radiological findings

The occlusal discrepancies found were few, because the occlusion was in every case adjusted before the prosthetic treatment and checked also at final examination after completion of the treatment, as well as at six-month follow-up by senior teachers, specialists in prosthetic dentistry and stomatognathic physiology. Also in the study of Yi et al. (1995) stable occlusion was found in most of the fixed bridges, while in the study of Ettala-Ylitalo *et al.* (1986) there were occlusal interferences in 98.6 % of the patients treated with fixed prostheses. The frequency of occlusal interferences was 34.9 % in crowned surfaces and 27.0 % in pontic areas.

The periodontal condition of the patients was generally good, only mild gingival bleeding on probing and calculus related to fixed prosthodontics was detected. One fixed bridge was extracted for periodontal reasons and in two cases the general periodontal situation was found to be poor in the clinical examinations (Papers IV and V). In other follow-up studies in the literature periodontal reasons were also only occasionally a reason for complications (Karlsson 1989), and it has been concluded that survival is not necessarily decreased by periodontally compromised teeth (Freilich *et al.* 1991, Yi *et al.* 1996). Reasons for the good periodontal condition of the patients may be the facts that during the preprosthetic periodontal treatment patients having a poor periodontal condition were especially motivated to maintain adequate home care to save their teeth, or that in the treatment planning other alternatives than fixed prostheses were chosen for these patients.

Although caries still seems to be the most common factor affecting complications (Schwartz *et al.* 1970, Randow *et al.* 1986, Walton *et al.* 1986, Libby *et al.* 1997), in this study caries was not a general problem (Papers IV and V). This could partly be explained by motivation for proper home care and fluoride therapy, but it must be kept in mind that not every invited patient did attend the follow-up examinations, and the patients who did not show up could have different clinical conditions and maybe more caries lesions. However, in cases where there is progressive caries which destroys the abutment, or abutments, caries is a huge problem. When there are not other caries lesions than in the abutment tooth the caries is most probably related to loss of retention, as Karlsson (1986) stated, but in the case of multiple caries lesions in the dentition the caries itself and the basic circumstances of the mouth are the problem. According to the results of this study, the low flow rate of saliva recorded before the prosthetic treatment, as well as high scores of mutans streptococci and lactobacilli seemed to increase complications (Paper V, Table 3; Table 8). Patients with a high risk of developing caries can be detected reliably by salivary tests performed in the early stages of the treatment: Vehkalahti *et al.* (1996) stated that a vast majority, 70 - 89 %, of the patients with a high-risk level of each salivary test developed new caries during the follow-up period (21 to 38 months), and they concluded that such critical salivary findings should always be taken into account and they should lead to intensified caries prevention in the treatment of these patients. It is also generally known that a low flow rate of saliva is a high risk factor for caries (Larmas 1987), and therefore all information about salivary findings should always be taken into account also in the treatment of patients who need fixed metal ceramic prostheses. In the future the treatment need for conventional fixed prosthodontics seems

to be highest among patients over 50 years of age (Paper I), and in that age group there is an increasing probability of having diseases and medication that may decrease the flow rate and change the quality of saliva. As Karlsson (1986) and Valderhaug (1991) also stated, intensified caries prevention is therefore important right from the start of the treatment to control the caries situation. Patients should also be encouraged to maintain adequate home care and regular recall with the dentist.

6.8 Late complications and survivals

6.8.1 Single metal ceramic crowns

In the 10-year follow-up examination 19 % of the single crowns were re-cemented, and in 7 % of the single crowns there were porcelain fractures (Paper IV). None of the patients attending the follow-up examination had lost a single metal ceramic crown, although it must be kept in mind that 50 % of the invited patients did not attend the examination and therefore there could have been more failures. In the evaluation of single crowns with dowels the most usual complication was root fracture, and loss of retention was the second most frequent one (Paper III, Table 2). In prosthodontic claims (Öwall *et al.* 1992) these reasons were also the most common ones, although there were more losses of retention than root fractures. Both of these complications could be assumed to relate to improper treatment planning or treatment procedures, and these procedures are emphasised in single crowns. Parallelism of the tooth surfaces does not help to the same extent as in fixed bridges and the tooth structure must be as ideal as possible when the loss of retention is considered. And the longer the dowel, the better the retention of the single crown with a dowel. However, the anatomy of the tooth must be kept in mind in order to prevent root perforations in preparing the root canal.

The most important factor of preparation design in preventing root fractures has been shown to be the ferrule effect, which is even more important than the design of the post (Assif *et al.* 1993). If the ferrule is not achieved, the preparation should be extended more subgingivally, or a surgical crown lengthening or orthodontic extrusion may be needed (Shillingburg *et al.* 1997). The length of the dowel also has an effect on root fractures in the same way as on the retention of the single crowns. The optimal length of the dowel has in mechanical studies been shown to be at least equal to the length of the root or, even better, two-thirds the length of the root (Sorensen & Martinoff 1984b, Standlee *et al.* 1972, Lambjerg-Hansen & Asmussen 1997). When tooth groups are considered, upper lateral incisors and upper first premolars are most prone to root fractures (Paper III). These teeth are anatomically complicated, because developmental invaginations and depressions of the tooth material exist and the canal anatomy is often oval or ribbon-shaped. In restoration of these teeth the more flexible carbon fibre posts might be a better choice than stiff dowels, but there is seldom enough dentin in these teeth to get proper adhesion for the carbon fibre posts. Therefore, in upper lateral incisors and upper first premolars the preservation of the tooth structure is important, which should be kept in mind right from the early stages of restorative treatment of these teeth.

The survival of the single metal ceramic crowns was counted based on previous restoration of the tooth (Paper III, Fig. 2). There were more complications in teeth with composite resin as a previous restoration and the complications occurred quite early in the life-span of the single crowns. After four years the survival was 86 % in this group, while in the group of one-piece dowel crown as a previous restoration the survival after four year was 100 % (Paper III, Table 3). The early failures of the single crowns with a composite resin as a previous restoration could be assumed to arise from different facts. Standlee *et al.* (1972) observed that high installation stresses are created in the coronal half of the root channel when rotating the screwed dowel in the root channel. The cementation procedure can cause wedge-like pressures in the root channel (Sorensen & Martinoff 1984a, Morgano & Milot 1993), which is why the screws have vertical grooves to enhance the cement flow. In addition, the prefabricated root canal screws seldom reach the optimal extension into the canal. All these factors may cause unnoticeable microfractures in the dentin and when the restoration is re-prepared, compression and stresses are caused again, and the risk for root fractures may increase. However, the difference between the survival of the composite resins and the one-piece dowel crowns as a previous restoration equalised after 72 months (last reported complication, Paper III, Table 3) and there was no statistical difference between the groups (survival rates were 84 % and 87 %, respectively) (Paper III, Fig. 2). However, it must be kept in mind, that the data were collected from the patient files, and therefore information of the patients who had visited a dentist outside the Institute of Dentistry is lacking from results. This could influence the survival rate in some extent.

6.8.2 Fixed metal ceramic bridges

In this study classification of the complications of fixed bridges according to the severity of the complications was introduced (Paper V, Table 2). Failure can also be assessed otherwise than total loss of the fixed bridge, and the classification here was established to obtain a better distribution of the complications and to distinguish severe complications from minor ones. Although caries has been the most usual reason for failures of fixed bridges (Schwartz *et al.* 1970, Randow *et al.* 1986, Walton *et al.* 1986, Libby *et al.* 1997), a minor lesion in the crown margin area is something quite different from the extensive caries which has destroyed the clinical crown under the retainer of a fixed bridge.

Based on two of the most severe classes of complications the survival rate for fixed bridges was calculated to be 84 % after ten years (Paper V, Fig. 1). The survival rate is quite similar to the meta-analytical study of Scurria *et al.* (1998), who estimated the survival rate to be 92 % after 10 years and 75 % after 15 years, and also to the study of Creugers *et al.* (1994), who calculated the survival rate to be 74 % after 15 years. Individual follow-up studies have also shown quite similar survival rates (Karlsson 1986, Karlsson 1989, Valderhaug 1991, Glantz *et al.* 1993, Leempoel *et al.* 1995, Sundh & Ödman 1997, Lindquist & Karlsson 1998) (Table 1). In this study it was not possible to count survival reliably after 10 years, due to the low number of fixed bridges, but it seems that after 15 years (180 months), which was the longest follow-up period, the survival is approximately 64 %. It has been noted in other studies as well that survival decreases

more sharply after 10 years (Karlsson 1989, Valderhaug 1991, Leempoel *et al.* 1995), which could technically be partly explained by fatigue of the materials used, such as metal alloys, porcelain and cement (Creugers *et al.* 1994). Loss of retention and recurrent caries probably also decrease the survival after 10 years (Scurria *et al.* 1998).

In this study long fixed bridges (five units and more) seemed to have lower survival than the shorter ones (Paper V, Table 3; Table 8). In literature there has been no consistent view on whether the length of the fixed bridge affects the survival (Reuter & Brose 1984, Foster 1991, Leempoel *et al.* 1995), although complications could be assumed to accumulate in long fixed bridges: tooth preparations are demanding and they may be over-tapered in an attempt to eliminate undercuts. In technical work there are also more problems in casting and fitting, and for patients the complicated bridgework may be more difficult to clean (Foster 1991), which increases the risk for biological complications.

The high number of endodontically treated teeth (3 – 6 versus 0 – 2) decreased the survival percent of the fixed bridges (Paper V, Table 3), which has been pointed out also in other studies. Loss of retention and fractures of both teeth and reconstructions have been shown to appear more frequently in distal, non-vital abutments (Randow *et al.* 1986, Nyman & Lindhe 1979, Karlsson 1986), which can partly be explained by the fact that non-vital teeth seem to have higher pain threshold levels than vital teeth (Randow & Glantz 1986). In the evaluation of prosthetic claims in Sweden a significantly high number of endodontically treated abutment teeth were related to complications in fixed bridges (Öwall & Cronström 2000), and in the study of Landolt & Lang (1988) 40 % of the failures were in non-vital abutments. However, in a clinical follow-up study of 23 - 25 years endodontically treated abutment teeth did not increase the risk for failure of fixed bridges (Palmqvist & Swartz 1993).

Practical clinical information is available in this study concerning the primary and late complications of fixed metal ceramic prostheses. The results of this study confirm the findings of earlier studies of the good long-term results of the conventional fixed prostheses, and form a solid ground for studies dealing exclusively with metal ceramic fixed prostheses.

7 Summary and conclusions

According to the results of this study, in the future the treatment need for conventional fixed metal ceramic bridges seems to be highest among patients over 50 years of age, and fixed bridges will most often be prepared to replace upper first premolars and lower first molars.

During the treatment phase the most usual primary complications and failures related to fixed bridges occur during preprosthetic endodontic treatment of abutment teeth and during the preparation of the root canals. The previous restoration of the prepared tooth did not have any marked effect on the prognosis of single crowns with dowels when comparing a composite resin restoration with screw post and a one-piece dowel crown. The cumulative survival rate after 72 months was 87 % for one-piece dowel crowns and 84 % for composite resins with screw post as a previous restoration. However, anatomically complicated upper lateral incisors and upper first premolars need special attention in the treatment planning.

The complications found in the clinical examinations were few and the patients were satisfied with the aesthetics and function of the fixed prostheses. The overall survival rate of fixed metal ceramic bridges was 84 % after 10 years, and long fixed bridges had a lower survival rate than the shorter ones. The age of the patient did not influence the survival of fixed bridges, but the basic circumstances of the mouth, especially low secretion of saliva affected by diseases and/or medications and high scores of lactobacilli and streptococcus mutans of the saliva should be taken into consideration in the planning of prosthetic treatment, since they seem to affect the occurrence of late complications and decrease the survival rate of the fixed prostheses.

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Appendices

Appendix 1. The data gathered from the patient files concerning the dental treatment of the patients treated with fixed metal ceramic prostheses during the years 1984 - 96

- gender
- age of the patient at the moment of cementation of the crown / bridge
- diseases
- medications
- salivary findings
  - flow rate of stimulated saliva
  - the score of mutans streptococci
  - the score of lactobacilli
- the primary treatment planning
- single crowns
  - metal ceramic veneer crown
  - cast dowel core and metal ceramic veneer crown
  - one-piece dowel crown
  - abutment tooth for removable partial denture
- fixed bridges
  - number of abutments per bridge
  - number of pontics of cantilever extension pontics per bridge
- reasons for prosthetic treatment
- occlusion
  - occlusion against the crown / bridge
  - stability of the occlusion
- periodontal condition
  - condition at the beginning of the treatment
  - condition at the beginning of the prosthetic treatment
  - periodontal surgery
- root canal therapies
  - former or done in the course of treatment
  - healing of the root canal therapy
  - complications
- structure of the abutment tooth / tooth prepared for crown
  - former restoration of the tooth
    - material used
    - pins for retention
    - root canal dowels / screws
  - extra retention
    - pin holes
    - grooves
- dental cement used
- the date the prosthesis was cemented
- complications
  - during the periodontal treatment

during the cariological treatment
during the prosthetic treatment
after the prosthetic treatment
recementations
six-month follow-up and treatment performed in the follow-up
periodontal follow-ups
cariological follow-ups
prosthetic follow-ups

Appendix 2. Anamnestic data and subjective opinions of the patients gathered in the clinical examinations.

How often you have visited the dentist after the prosthetic treatment?
- more often than once in a year
- once in a year
- only if necessary

Have you been satisfied with the crowns / bridges?
- aesthetics
- colour
- shape
- glossy finish

Have there been any symptoms around the crowns / bridges?
- pain
- sensitivity to cold
- sensitivity to heat
- cervical root sensitivity
- gingival bleeding
- mobility

Have the fitting of the crowns / bridges affected the speech?
- yes / no
- how?

Home care and tooth cleaning
- more than once in a day
- once a day
- less frequently than once a day
- toothbrush
- toothpaste
- dental floss
- floss for the bridges
- interproximal brushes
- toothpicks

Do you have any difficulties in cleaning?

Do you have any problems with crowns / bridges?
- fracture of the porcelain
- mobility
- rupture of the bridge
- loss of retention

Do you have any other comments of the treatment?
