Long-term Results of Short-Span Versus Long-Span Fixed Dental Prostheses: An Up to 20-Year Retrospective Study

Hein De Backer, DDS, MScD, PhD[a]/Georges Van Maele, PhD[b]/Nathalie De Moor, DDS[c]/
Linda Van den Berghe, DDS, MScD, PhD[d]

Purpose: This study of short-span fixed dental prostheses (Ss-FDPs) versus long-span FDPs (Ls-FDPs) evaluated the long-term efficacy and determined the frequencies and causes of failures. ***Materials and Methods:*** A total of 236 Ss-FDPs and 86 Ls-FDPs made in an undergraduate university clinic for 149 and 70 patients, respectively, were evaluated over a 20-year period. Kaplan-Meier analysis with a 95% confidence interval was used to estimate the survival probability. Failures of the FDPs were divided into irreversible (loss of FDPs or finish line involvement) or reversible (FDPs and abutments intact after conservative treatment) complications and into biologic and technical/patient-related failures. ***Results:*** The overall survival estimations for Ss-FDPs (70.8%; 95% CI: 63%–79%) and Ls-FDPs (52.8%; 36%–70%) at year 20, were statistically significantly different ($P = .030$). There was no statistically significant difference ($P = .126$) for the survival estimations for Ss-FDPs (60.4%; 48%–73%) versus Ls-FDPs (59.0%; 44%–74%) at year 19 in the root-canal treated (RCT) group. For the Ss-FDPs group there was a statistically significant difference ($P = .009$) between the vital (82.4%; 73%–92%) and RCT (60.4%; 49%–73%) groups at year 20. The reason for failure in the Ss-FDP group was of biologic origin in 55.6% to 66.7% of cases, but for the Ls-FDP group the failures were of technical origin in 56.0% to 84.0% of cases. ***Conclusion:*** The survival of Ss-FDPs and Ls-FDPs over a 20-year period was favorable. The overall survival estimation for Ss-FDPs was statistically significantly better than for Ls-FDPs at year 20. The use of an RCT abutment becomes more significant in fixed prosthetic restorations with 4 or more units. Occurrence of a previously reversible complication is a predictive factor for an irreversible complication later on. A reversible complication within the first 2 years for an Ss-FDP will lead to an irreversible complication. *Int J Prosthodont 2008;21:75–85.*

Survival studies of fixed prosthetic restorations are usually based on long-span fixed dental prostheses (Ls-FDPs).[1–14] Whenever results of short-span FDPs (3 or 4 units) (Ss-FDPs) are reported, they are part of broader surveys.[15–19] All of these longitudinal studies aim to measure the life span of the FDPs and determine the causes of failures in a certain time frame. In general, however, comparing the data on the survival of FDPs is difficult. The differences between surveys are commented on in meta-analyses.[20–22] They all report the need for standardization of the terminology and the consequent use of scientific rules in the study design. However, this kind of study is difficult to perform and evaluate because of the power of the study required, the sometimes high number of dropouts, the need for complete recording of the data, and the large number of variables in the statistical analysis. Stability of a studied population is important for the results of a longitudinal survey.

Survival studies measuring the life span of fixed prosthetics and determining causes for failure should

[a]*Senior Researcher, Centre for Special Care, PaeCaMed Research, Unit of Gnathology and Temporomandibular Disorders, Dental School, Faculty of Medicine and Health Sciences, Ghent University, Belgium.*
[b]*Professor, Department of Medical Statistics, Faculty of Medicine and Health Sciences, Ghent University, Belgium.*
[c]*Private Practice, Ghent, Belgium.*
[d]*Professor, Centre for Special Care, PaeCaMed Research, Unit of Gnathology and Temporomandibular Disorders, Dental School, Faculty of Medicine and Health Sciences, Ghent University, Belgium.*

Correspondence to: *Dr Hein De Backer, Hulststraat 8, 8700 Tielt, Belgium. E-mail: hein.debacker@skynet.be*

provide researchers, clinicians, and their patients with valuable prognostic information. For the patient, the estimated survival time, possible causes of failure, and feasible methods for repair are important. Patients are concerned about what happens when failure occurs and whether their problems can be solved with the full prosthetic restoration still in place (reversible complication). Failure is defined as (partial) loss of the fixed prosthetic restoration with or without loss of abutment(s) (irreversible complication). Generally, the reasons for failure are patient or clinician related. If longitudinal survival studies measure only the quality of the materials used, the definition of failure should be very strict. Each in vivo incident should be classified as a mechanical failure.

For the clinician, the calculated survival time for each type of fixed prosthetic treatment is important, depending on the incidence of a reversible complication over time. Further, the existence of an indicator for the time of failure (early or late reversible/irreversible complication) would be of interest. The definition of failure can be universal in terms of the patient and practitioner. For the general practitioner and researcher, the definition can be universal in use, according to the estimated survival time and the possible causes of failure. Only when the quality of the material itself is tested in vitro should the definition be strict (mechanical failure).

Generally, longitudinal survival studies[16–19] found no relationship between the duration of service of the fixed prosthesis and the number of units. Reuter and Brose[1] concluded that a trend for failure appeared to be associated with longer FDPs. Four surveys[15,23–25] found a clear relationship between the life span and number of units. Therefore, the aim of this retrospective study was to evaluate the long-term survival of Ss-FDPs and Ls-FDPs and to determine frequencies and causes of failure.

Materials and Methods

Material

All FDPs made over a period of 20 years, between 1974 and 1992, in the undergraduate clinic of the former department of Fixed Prosthodontics and Periodontology at the university clinic in Ghent were used for this study. A total of 397 FDPs were made during that period. Cantilever FDPs were not included.

Complete treatment and follow-up records of 193 patients (62% women and 38% men) with 322 FDPs were available for analysis, representing 81% of the total number of FDPs. In this group, 39.1% (n = 126) of the FDPs were placed in the maxilla and 60.9% (n = 196) were placed in the mandible. Of the total patients, 60.1% (n = 116) received 1 FDP, 22.3% (n = 43) received 2 FDPs, 9.8% (n = 19) received 3 FDPs, 6.2% (n = 12) received 4 FPDs, and 1.6% (n = 3) received 5 FDPs. This represented 1,308 fixed units with a total of 704 abutments and 604 pontics. The mean number of units per FDP was 4.1, and the pontic/abutment ratio was 0.86. On average, 2.2 abutments and 1.9 pontics were made per FDP. Sixty-five percent of the abutment teeth were vital at the time of preparation, while 35% had a post and core. The group of FDPs with 2 abutment teeth represented 84.5% of the total number, while 12.4% had 3 abutment teeth and 3.1% had 4 abutment teeth. Of the FDPs with 3 or 4 abutments, 10.5% had an intermediate abutment tooth and 5.0% included 2 abutments at the end. In terms of the number of pontics, 42.5% of FDPs had 1 pontic, 37.3% had 2 pontics, and the remaining 20.2% of FDPs had 3 pontics (11.5%), 4 pontics (7.8%), 5 pontics (0.6%), or even 6 pontics (0.3%). The distribution of the units per FDP was as follows: 41.6% were 3-unit FDPs, 31.7% were 4-unit FDPs, 12.1% were 5-unit FDPs, 10.9% were 6-unit FDPs, and 3.7% were 7- to 9-unit FDPs.

The dropout rate of 19% was caused by the following: patients chose a private practitioner for maintenance, moved to another city, could not be traced, or died during the follow-up period. None of the patients in the dropout group were contacted by telephone and no questionnaires were sent to these patients or their former or current clinicians to collect supplementary information.

The investigated sample was divided into 2 groups: *(1)* a short-span group (Ss-FDPs) with 236 FDPs in 149 patients (63.1% women and 36.9% men) with a mean age of 63.0 years (range: 33.6 to 94.2 years); and *(2)* a long-span group (Ls-FDPs) with 86 FDPs in 70 patients (57.1% women and 42.9% men) with a mean age of 66.7 years (range: 41.8 to 88.6 years). A small group of patients had both types of FDPs and consequently were involved in both groups. The FDPs consisted of porcelain-fused-to-gold or gold retainers. Abutments in the anterior region were always covered with porcelain. Abutments on molars were gold or porcelain-fused-to-gold restorations, depending on the esthetic choice of the patient or the technical preference of the practitioner. In the posterior region, most abutments had a supragingivally located margin. For esthetic reasons, the abutment margin in the anterior region was located at the gingival margin.

No special root canal preparations for the post-and-core abutment teeth were used to avoid excessive removal of dentin substance. A standard ferrule of 2 mm was preferred, but in many cases this could not be obtained. Many post-and-core preparations had a limited ferrule. No direct restorative techniques or special burs with prefabricated posts were used. At least 10 mm (range: 7 to 15 mm) of the root canal fill-

ing was removed, according to standard protocol. The impression of the prepared tooth was always made with the same polyether material (Impregum, 3M ESPE). The impression of the root canal was made with the help of a lentulo, but no other devices such as burnout posts were used. All cast gold posts and cores on the abutment teeth were made separately from their retainer. Posts and cores were made of the same gold alloy (Degudent U, Degussa) used for the abutments and pontics. No posts and cores made with a direct buildup technique were included in this study. No additional parapulpal pins to increase retention were used. All retentive surfaces of the restorations were sandblasted (50 μm) during the last laboratory phase, prior to cementation. All FDPs were cemented with zinc phosphate cement (Harvard, Richmond Harvard) under strict conditions. This project (EC UZG 2005/100) was approved by the Ethics Committee, OG 017, University Hospital, Ghent, Belgium.

Methods

All patients were offered a regular supportive maintenance program on a 6-month basis. The purpose of these maintenance sessions was extensively described in a previous report.[23] Only patients who agreed to attend the supportive maintenance program were evaluated, as long as they were present on a regular basis. A number of patients interrupted this program or preferred to visit a private practitioner. All of these patients received an invitation by mail, on a single occasion, for a free checkup. During this final evaluation session, diagnostic and therapeutic steps were undertaken according to the standard protocol extensively described in a previous report,[23] thus reintegrating this patient group in the study results. The Kaplan-Meier survival estimation method with a 95% confidence interval was used.[26] Failures were divided into biologic or technical/patient-related failures and into reversible or irreversible complications. Biologic failures comprised caries, periodontal problems, fracture of the abutment tooth, and endodontic problems. Technical/patient-related failures comprised loss of retention and fracture of the framework. Failures were defined as irreversible complications if there was finish line involvement or if the FDP or a tooth were lost and as reversible complications when re-cementation after loss of retention or endodontic treatment/filling of an abutment tooth was required with the FDP and finish line still intact. An FDP may have had a reversible complication and ended up in the surviving group at the final evaluation or may have had a reversible complication followed by an irreversible complication, thus ending up in the failing group.

Table 1 Distribution of Ss-FDPs and Ls-FDPs in the Maxilla and Mandible in the Vital and RCT Groups

	Vital group	RCT group	Total (%)
Ss-FDPs			
Maxilla	53	40	93 (39.4)
Mandible	56	87	143 (60.6)
Total (%)	109 (46.2)	127 (53.8)	236 (100)
Ls-FDPs			
Maxilla	20	13	33 (38.4)
Mandible	13	40	53 (61.6)
Total (%)	33 (38.4)	53 (61.6)	86 (100)

Table 2 Frequency Distribution of Ss-FDPs Per Patient and the No. of Ss-FDPs Failed or Surviving Within the Same Patient

FDP/patient	No. failed	No. of patients
1 (62.4%)	0	75
	1	18
2 (23.5%)	0	26
	1	6
	2	3
3 (7.4%)	0	5
	1	3
	2	2
	3	1
4 (6.7%)	0	5
	1	4
	2	1

Statistical Analysis

The Kaplan-Meier survival estimation method with a 95% confidence interval was used.[26] The log-rank test was used to discover whether some survival functions differed between groups.[27] The Mann-Whitney *U* test was used to compare irreversible complications between the 2 groups. Statistical significance was calculated using the chi-square test (Fisher exact test). The significance level was set at $\alpha = .05$.

Results

Descriptive Data

A total of 236 Ss-FDPs were made for 149 patients, with a mean survival follow-up time of 11.6 years (range: 1.0 to 26.3 years). A total of 86 Ls-FDPs were made in 70 patients, with a mean survival follow-up time of 10.9 years (range: 0.5 to 23.7 years). Table 1 shows the distribution of all Ss-FDPs and Ls-FDPs. For the whole investigated group, the antagonist was natural dentition in 57.1% of the patients, an FDP in 37.8%, and a complete denture or an edentulous space in 5.1%.

Regarding the number of prostheses, 62.4% (n = 93) of patients received 1 Ss-FDP, 23.5% (n = 35) received

Table 3 Frequency Distribution of Ls-FDPs Per Patient and the No. of Ls-FDPs Failed or Surviving Within the Same Patient

FDP/patient	No. failed	No. of patients
1 (80.0%)	0	44
	1	12
2 (17.1%)	0	6
	1	4
	2	2
3 (2.9%)	3	2

2 Ss-FDPs, 7.4% (n = 6) received 3 Ss-FDPs, and 6.7% (n = 10) received 4 Ss-FDPs. Table 2 shows the number of Ss-FDPs placed per patient, the number of failed or surviving restorations within the patient, and the frequency distribution in the study population. One patient (2.6%) had 3 failing FDPs, 6 patients (15.8%) had 2 failing FDPs, and 31 patients (81.6%) had only 1 failing FDP. Complications were not more likely in any particular patient. Only 19.5% (n = 46) of the FDPs placed in this group failed, and 25.5% of the patients had 1, 2, or 3 failing FDPs.

Regarding Ls-FDPs, 80.0% (n = 56) of patients received 1 Ls-FDP, 17.1% (n = 12) received 2 Ls-FDPs, and 2.9% (n = 2) received 3 Ls-FDPs. Table 3 shows the number of Ls-FDPs placed per patient, the number of failed or survived restorations within the patient, and the frequency distribution in the study population. Two patients (10.0%) had 3 failing FDPs, 2 patients (10.0%) had 2 failing FDPs, and 16 patients (80.0%) had only 1 failing FDP. Complications were not more likely in any particular patient. Of all FDPs placed in this group, 30.2% (n = 26) failed, and 28.6% of the patients had 1, 2, or 3 failing FDPs.

Kaplan-Meier Survival Curves

Figures 1 to 3 show the Kaplan-Meier survival curves for the Ss-FDPs and Ls-FDPs overall and in the maxilla and mandible. For the overall estimation (Fig 1), there was a statistically significant difference (log-rank, P = .030) between the Ss-FDPs and Ls-FDPs at year 20. The survival estimation for Ss-FDPs was 94.6% (95% CI: 92%–98%) at year 5, 84.4% (79%–90%) at year 10, 73.4% (66%–81%) at year 15, and 70.8% (63%–79%) at year 20. For Ls-FDPs, the survival estimation was 88.3% (82%–95%) at year 5, 73.2% (63%–84%) at year 10, 69.3% (58%–80%) at year 15, and 52.8% (36%–70%) at year 20.

Regarding the survival estimation for the maxilla (Fig 2), there was no significant difference (P = .671) between the groups. The survival estimation for Ss-FDPs in the maxilla was 93.3% (88%–99%) at year 5, 82.7% (74%–92%) at year 10, 64.6% (51%–78%) at year 15, and 61.2% (47%–75%) at year 20. For Ls-FDPs in the maxilla, the survival estimation was 90.9% (81%–100%) at year 5, 76.6% (59%–94%) at year 10, 70.7% (51%–90%) at year 15, and 56.5% (33%–80%) at year 20.

Comparing the survival estimations for the mandible (Fig 3), there was a highly statistically significant difference between the groups (P = .009). The survival estimation for Ss-FDPs in the mandible was 95.5% (92%–99%) at year 5, 85.4% (79%–92%) at year 10, 79.5% (71%–88%) at year 15, and 77.5% (68%–87%) at year 19. For Ls-FDPs in the mandible, the survival estimation was 82.8% (72%–93%) at year 5, 70.8% (58%–84%) at year 10, 67.8% (54%–82%) at year 15, and 60.3% (42%–79%) at year 19.

Figures 4 and 5 show the Kaplan-Meier survival curves for the Ss-FDPs and Ls-FDPs in the vital and root canal–treated (RCT) groups. Regarding the survival estimation for the vital group (Fig 4), no statistically significant difference was found between the Ss-FDPs and Ls-FDPs (P = .186). For Ss-FDPs in the vital group, the survival estimation was 97.1% (94%–100%) at year 5, 91.7% (86%–98%) at year 10, and 82.4% (73%–92%) at years 15 and 20. For Ls-FDPs in the vital group, the survival estimation was 90.8% (81%–100%) at year 5, 86.9% (75%–99%) at years 10 and 15, and 63.0% (38%–88%) at year 20. The survival estimation for the RCT group (Fig 5) between the Ss-FDPs and Ls-FDPs showed no statistically significant difference (P = .126). For Ss-FDPs in the RCT group, the survival estimation was 93.5% (89%–98%) at year 5, 78.2% (70%–87%) at year 10, 65.7% (55%–77%) at year 15, and 60.4% (48%–73%) at year 19. For Ls-FDPs in the RCT group, the survival estimation was 84.8% (75%–94%) at year 5, 65.1% (51%–79%) at year 10, and 59.0% (44%–74%) at years 15 and 19.

For the Ss-FDPs, the Kaplan-Meier survival curves for the vital and RCT groups are presented overall (Fig 6) and in the maxilla (Fig 7) and mandible (Fig 8). For the overall estimation (Fig 6), there was a statistically significant difference (P = .009) between the vital and RCT groups at year 20. The survival estimation for the vital group was 97.1% (94%–100%) at year 5, 91.7% (86%–98%) at year 10, and 82.4% (73%–92%) at years 15 and 20. For the RCT group, the survival estimation was 93.5% (89%–98%) at year 5, 78.2% (70%–87%) at year 10, 65.7% (55%–77%) at year 15, and 60.4% (49%–73%) at year 20. Comparing the survival estimations for the maxilla (Fig 7), there was a borderline missed significant difference between the groups (P = .060). The survival estimation for the vital group in the maxilla was 94.0% (87%–100%) at year 5, 88.5% (79%–98%) at year 10, and 71.6% (56%–87%) at years 15 and 20. For the RCT group in the maxilla, the survival

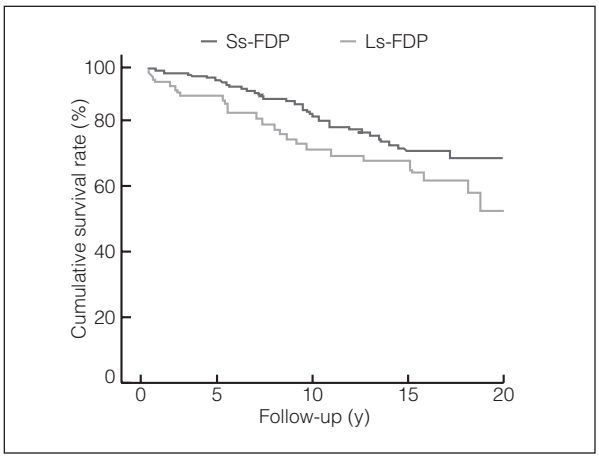

Fig 1 Kaplan-Meier survival curves for Ss-FDPs and Ls-FDPs overall ($P = .030$).

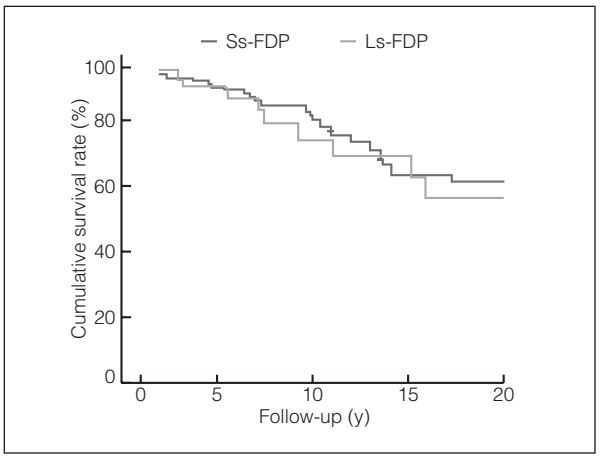

Fig 2 Kaplan-Meier survival curves for Ss-FDPs and Ls-FDPs in the maxilla ($P = .671$).

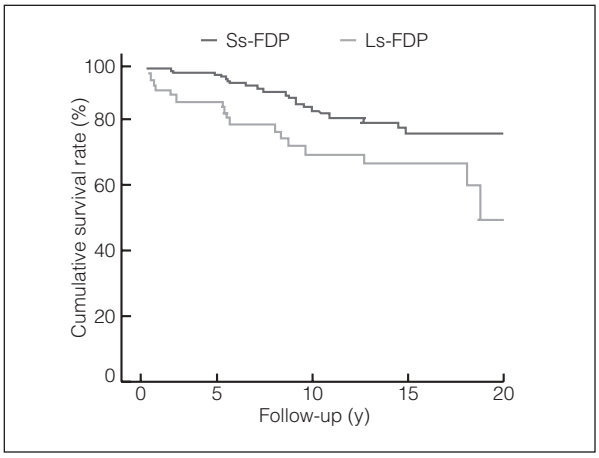

Fig 3 Kaplan-Meier survival curves for Ss-FDPs and Ls-FDPs in the mandible ($P = .009$).

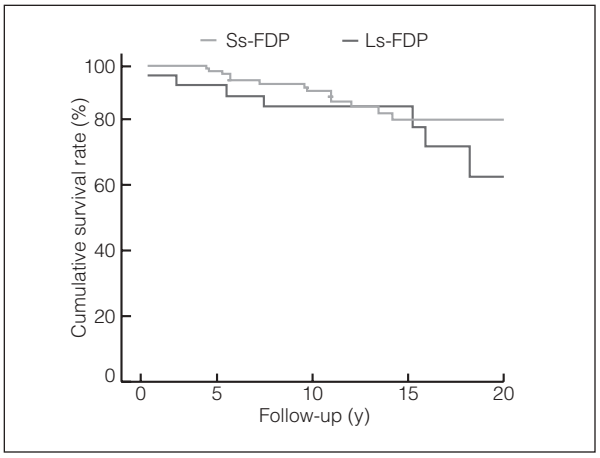

Fig 4 Kaplan-Meier survival curves for Ss-FDPs and Ls-FDPs in the vital group ($P = .186$).

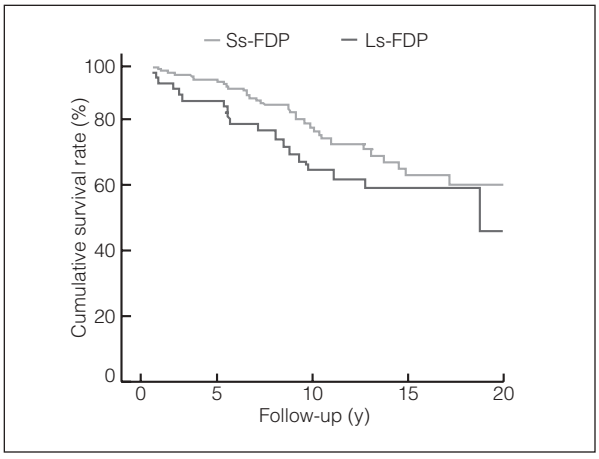

Fig 5 Kaplan-Meier survival curves for Ss-FDPs and Ls-FDPs in the RCT group ($P = .126$).

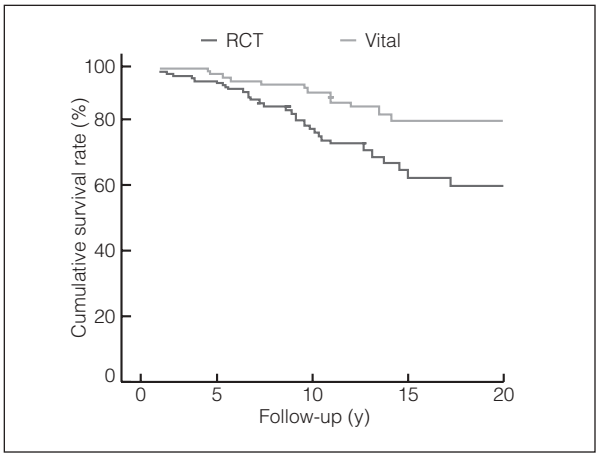

Fig 6 Kaplan-Meier survival curves for the vital and RCT groups overall ($P = .009$).

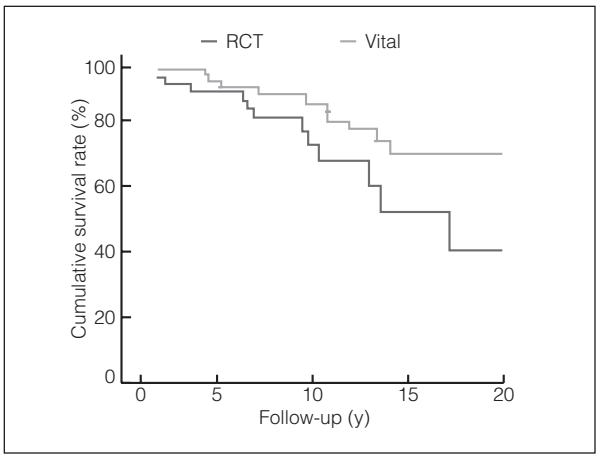

Fig 7 Kaplan-Meier survival curves for the vital and RCT groups in the maxilla ($P = .060$).

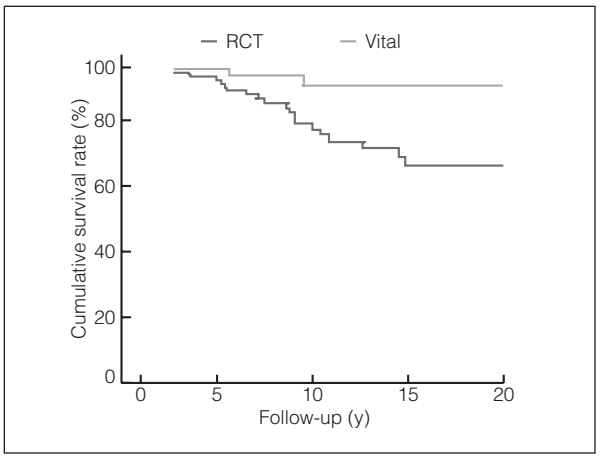

Fig 8 Kaplan-Meier survival curves for the vital and RCT groups in the mandible ($P = .008$).

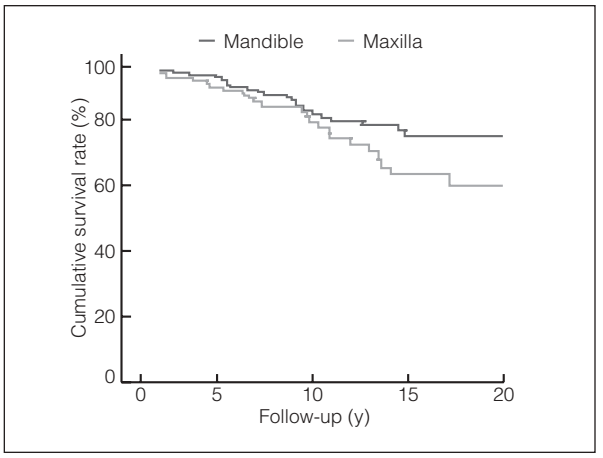

Fig 9 Kaplan-Meier survival curves for the maxilla and mandible overall ($P = .087$).

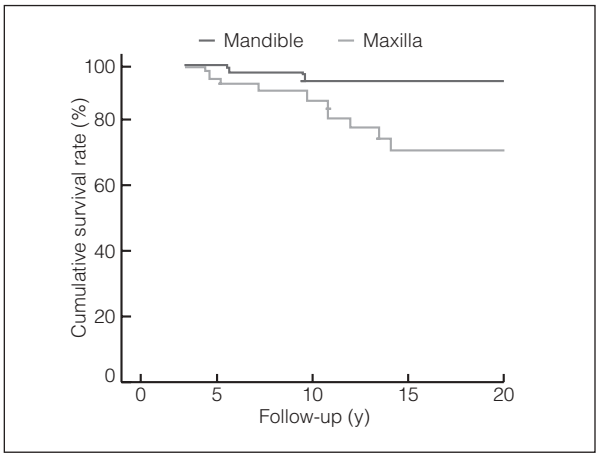

Fig 10 Kaplan-Meier survival curves for the maxilla and mandible in the vital group ($P = .031$).

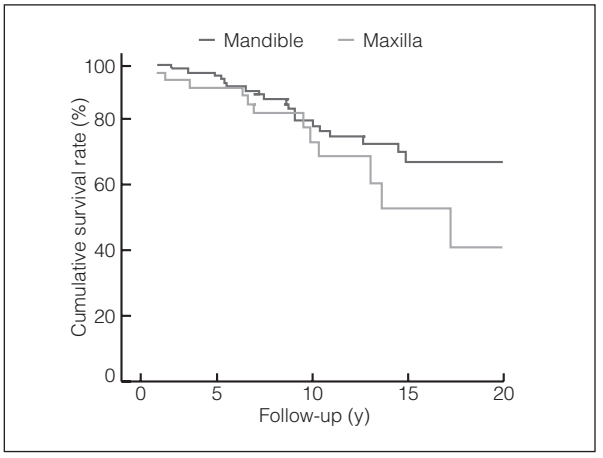

Fig 11 Kaplan-Meier survival curves for the maxilla and mandible in the RCT group ($P = .178$).

estimation was 92.5% (84%–100%) at year 5, 74.1% (58%–91%) at year 10, 51.9% (27%–77%) at year 15, and 38.9% (10%–68%) at year 20. Regarding the survival estimation for the mandible (Fig 8), there was a statistically significant difference ($P = .008$) between the vital and RCT groups at year 20. The survival estimation for the vital group in the mandible was 100% at year 5 and 94.8% (88%–100%) at years 10, 15, and 20. For the RCT group in the mandible, the survival estimation was 92.8% (87%–98%) at year 5, 79.7% (70%–90%) at year 10, 70.4% (58%–83%) at year 15, and 67.4% (54%–81%) at year 20.

For Ss-FDPs, the Kaplan-Meier survival curves for the vital and RCT groups are presented overall (Fig 9) and in the maxilla (Fig 10) and mandible (Fig 11). For the overall estimation (Fig 9), there was no statistically significant difference ($P = .087$) between the vital and RCT groups at year 20. The survival estimation in the maxilla was 93.3% (88%–99%) at year 5, 82.7%

(74%–92%) at year 10, 64.6% (51%–78%) at year 15, and 61.2% (47%–75%) at year 20. In the mandible, the survival estimation was 95.5% (92%–99%) at year 5, 85.4% (79%–92%) at year 10, 79.5% (71%–88%) at year 15, and 77.5% (68%–87%) at year 20. Regarding the survival estimation for the vital group (Fig 10) (mentioned earlier), a statistically significant difference was found between the maxilla and mandible (P = .031). The survival estimation for the RCT group (Fig 11) (mentioned earlier) between the maxilla and mandible revealed no statistically significant difference (P = .178).

Reasons for Failure

The reasons for irreversible complication of Ss-FDPs and Ls-FDPs are presented in Table 4. The main reason for an irreversible complication of Ss-FDPs was caries (35.6%). For Ls-FDPs, the main reasons were fracture of the FDP (24.0%) and loss of retention (24.0%). For the Ss-FDPs, fracture of the FDP and loss of retention both occurred in 11.1% of cases. Comparing these 2 irreversible complications, Ss-FDPs versus Ls-FDPs revealed a borderline missed statistically significant difference (Fisher exact test, P = .074). For Ls-FDPs, there were no irreversible complications caused by caries. A combined group for caries and loss of retention was made because the main reason could not be determined with certainty. This group accounted for 22.2% of irreversible complications for the Ss-FDPs and 28.0% for the Ls-FDPs. The mean survival times of FDPs with these irreversible complications are shown in Table 5.

Cross-tabulations of the surviving restorations versus the failing restorations, with reversible complication as dependent variable, are presented in Table 6 for the Ss-FDPs and Ls-FDPs. In the surviving group of the Ss-FDPs, only 9.5% had a reversible complication, while in the failing group, 26.1% had a reversible complication. This was a statistically significant difference (P = .005). For the Ls-FDPs, 18.3% of the FDPs in the surviving group had a reversible complication, while in the failing group, 46.2% had a reversible complication. This was a statistically significant difference (P = .015). Occurrence of a previous reversible complication is a predictive factor for an irreversible complication later on.

For the Ss-FDPs and Ls-FDPs, these reversible complications were divided into an early reversible complication group (failure within 2 years) and a late reversible complication group (failure occurring after more than 2 years). For the failing restorations in the Ss-FDP group, the mean survival time of the early reversible complication group was 9.0 years, while the mean survival time of the late reversible complication group was 14.9 years, which represents a statistically significantly difference (P = .007). For the failing Ls-FDPs, the mean survival time of the early reversible complication group was 11.8 years, while the mean survival time of the late reversible complication group was 13.5 years, which was not statistically significantly different (P = .466). Dividing the Ls-FDPs into an early reversible complication group (failure within 5 years) with a mean survival time of 11.3 years and a late reversible complication group (failure occurring after more than 5 years) with a mean survival time of 16.6 years revealed a statistically significant difference (P = .039).

Table 4 Reasons for (Biologic* and Technical†) Irreversible Complications (%) for Ss-FDPs and Ls-FDPs

	Ss-FDPs	Ls-FDPs
Caries*	35.6	0
Loss of retention†	11.1	24.0
Caries/loss of retention*,†	22.2	28.0
Fracture framework†	11.1	24.0
Fracture retainer*	6.8	12.0
Periodontal problems*	4.4	4.0
Endodontic/apical*	4.4	0
Esthetic†	0	8.0
New retainer*	4.4	0

Table 5 Mean Survival Time (y) for Caries and Loss of Retention in Ss-FDPs and Ls-FDPs

	Ss-FDPs	Ls-FDPs
Caries	11.6	0
Loss of retention	9.5	5.9
Caries/loss of retention	9.7	6.9

Table 6 Cross-Tabulation for Ss-FDPs and Ls-FDPs of Surviving Restorations Versus Failed Restorations, with Reversible Complication as the Dependent Variable

Reversible complication	Ss-FDPs*		Ls-FDPs**	
	Surviving	Failed	Surviving	Failed
No (%)	172 (90.5)	34 (73.9)	49 (81.7)	14 (53.8)
Yes (%)	18 (9.5)	12 (26.1)	11 (18.3)	12 (46.2)
Total	190	46	60	26

*P = .005; **P = .015.

Discussion

The aim of the present study was to evaluate the survival of conventional short-span and long-span FDPs and to determine frequencies and causes of failure. Results of cantilever FDPs were not included because combining research groups of 2 different treatment modalities would lead to a misrepresentation of the results.

The survival of Ss-FDPs can only be compared with other survival studies of mainly Ls-FDPs[1–14] and meta-analyses of FDPs.[20–22] Generally, survival studies mentioned functional life spans or life spans before failure of 3- and 4-unit FDPs combined as a short-span FDP group or cited survival estimations for split 3- and 4-unit FDPs[15–19] but drew different conclusions. No other topics were addressed. Kerschbaum and Leempoel[17] reported survival rates for Ss-FDPs of 2 different population groups. A study group with results derived from private practitioners revealed survival rates of 92.2% after 10 years and 86.8% after 12 years, while a group with results extracted from insurance documents showed a survival rate of 90.2% after 8 years. Failure-related studies have reported a mean duration of service ranging from 6.3[19] to 6.6 years[18] for Ss-FDPs and 9.6[16] to 12.3 years[15] for 3- and 4-unit FDP groups, combined. These latter studies found a mean duration of services for their total group ranging from 6.1 to 10.3 years. In the present study of conventional Ss-FDPs, the survival estimation was 94.6% after 5 years, 84.4% after 10 years, 73.4% after 15 years, and 70.8% after 20 years. These results are partially comparable with other results published, but no results after 15 or 20 years were found in the literature.

The survival estimations for Ls-FDPs in the present study were 88.3% after 5 years, 73.2% after 10 years, 69.3% after 15 years, and 52.8% after 20 years. These results can be compared with other survival studies of Ls-FDPs[1–19] and meta-analyses of FDPs.[20–22] Unfortunately, only 7 studies were published between 1970 and 2006 reporting results for the survival of FDPs after 20 years of function.[6,10,11,13,14,23,28] The evaluation of these clinical follow-up studies is difficult because of variations in study design, material, and definition of failure. The prosthetic treatments have been carried out by general practitioners,[11,13,28] in a specialized clinic,[6] or by undergraduate students in a dental school.[10,14,23] Most researchers pooled FDPs and cantilever FDPs,[6,11,13,14] or the presence or absence of cantilever FDPs was not detectable in the material.[10,28] Some studies used questionnaires or telephone interviews,[11,13,14,28] some had large dropout rates,[6,10,11,13,28] and some had research groups consisting of complete crowns and/or Ss-FDPs and Ls-FDPs.[6,10,13,14,23,28] Allowing for these variables, a survival estimation of 52.8% after 20 years for FDPs with $\geq$ 5 units seems realistic. One of the most important findings in the present study was that a relatively expensive treatment with FDPs seems to be an acceptable, reliable, and financially worthwhile treatment over a long period of time. This is in agreement with previous studies.[6,13]

It is important for studies to mention the number of units in the FDPs investigated, and the study group should be well defined. There is a variety of groups of FDPs studied in the literature.[1–14,28–30] Roughly, these studies can be divided into 3 main groups: *(1)* studies of FDPs with a mean number of units in function between 6.7 and 6.9,[2–4,6,7,11,13] *(2)* studies of FDPs with a mean number of units in function between 3.5 and 4.5,[8,9,14] and *(3)* studies of FDPs with 2 to 14 units in function.[1,5,10,12,28–30] In this latter group, 4 studies do not mention a mean value,[1,5,28,30] 2 studies had a median of 3 units[29] or a mean of 3.6 units,[12] and 1 study[10] investigated FDPs with 2 to 4 units (56.6%) and $\geq$ 5 units (43.4%). Comparing these studies could lead to misinterpretation and incorrect conclusions. The present FDP group was examined at 3 different levels: *(1)* the whole group of 322 FDPs[23] with an estimated survival of 66.2% at year 20, *(2)* the FDP group (n = 188) without the 3-unit FDPs[24] with an estimated survival of 61.5% at year 20, and *(3)* the Ls-FDP group (FDPs $\geq$ 5 units, n = 86) with an estimated survival of 52.8% at year 20.

For the overall comparison of the Ss-FDPs and Ls-FDPs at year 20, there was a statistically significant difference ($P = .030$). Most studies[8,12,16–19] found no relationship between the duration of service and the number of units. Reuter and Brose[1] concluded that there was a trend for failures to be associated with longer FDPs. Four surveys[15,23–25] found a clear relationship between the life span and number of units. More specific, there was a highly significant difference ($P = .009$) between the survival of Ss-FDPs and that of Ls-FDPs in the mandible. It seems reasonable to state that fixed prosthetic restorations should be as simple as possible. Extra abutments do not mean extra security; on the contrary, they carry statistically significantly more risk for irreversible complications.

No statistically significant difference ($P = .087$) was found between the overall survival for Ss-FDPs in the maxilla and mandible. This is in agreement with other surveys.[6,23,24,30] However, it is in contrast with the results of Kerschbaum et al[31] and Hochman et al,[32] both of whom found that failures occurred more frequently in the maxilla. On the other hand, Palmqvist and Söderfeldt[33] found a substantially higher risk of losing an abutment tooth in the mandible compared to the maxilla. Subdividing this overall group into vital and RCT groups revealed a statistically significant difference ($P = .031$) between the vital group in the maxilla (71.6%) and mandible (94.8%) at year 20. Both groups were equally distributed. For the RCT group, there was no statistically significant difference ($P = .178$).

The overall survival of Ss-FDPs in the vital group compared with that of the RCT group revealed a highly statistically significant difference ($P = .009$) at year 20. The use of an RCT abutment was significantly more prone to failure of the Ss-FDPs. These results are

comparable with some studies[14,16,33] but statistically different from others.[8,10,24] Subdividing this overall group into the maxilla and mandible, a highly statistically significant difference ($P = .008$) was found in the mandible between the vital (94.8%) and RCT (67.4%) groups at year 20. In the maxilla, a borderline statistically significant difference ($P = .060$) was found. Vital Ss-FDPs in the mandible are significantly better than vital Ss-FDPs in the maxilla and RCT Ss-FDPs in the mandible. In the present study group, an Ss-FDP without RCT abutments in the mandible had the smallest number of irreversible complications. These results are confirmed by the same authors in 2 other survival studies of FDPs.[23,24] For Ss-FDPs, there was a trend for maxillary FDPs in the RCT group to be inferior in quality to vital Ss-FDPs in the maxilla and Ss-FDPs in the mandible. Comparing the vital groups between the Ss-FDPs (82.4%) and Ls-FDPs (63.0%) revealed no statistically significant difference ($P = .186$) at year 20. Evaluating the RCT groups between the Ss-FDPs (60.4%) and Ls-FDPs (44.3%) also showed no statistically significant difference ($P = .126$). Linking the latter results with those from studies of complete crowns,[34] 3-unit FDPs,[24] and 4-unit FDPs (unpublished data) at the same university, no statistically significant difference was found between the vital and RCT groups after 18 and 20 years of function for the complete crowns and 3-unit FDPs; however, a statistically significant difference was found for 4-unit FDPs. Thus, it can be concluded that the use of an RCT abutment becomes more significant in fixed prosthetic constructions with 4 or more units. The latter sequence of studies, in combination with the results of the present study on FDPs with $\geq$ 5 units, have the advantage compared to most other published studies that they had no amalgamation of FDPs with different numbers of units or different treatment options. Considering the statistically significant relationship between the use of an RCT abutment, the duration of service of FDPs, and the number of units that were used, one may conclude that fixed prosthetics should be kept as simple as possible. Blocking of complete crowns or Ss-FDPs or the use of extra abutments for an equal replacement of missing teeth, which enlarges the number of units, will be less favorable in terms of survival. Consequently, the treatment plan could be improved by using dental implants to avoid FDPs with $\geq$ 5 units or FDPs with $\geq$ 4 units if an RCT abutment would be involved.

In the Ss-FDP group, the main reason for irreversible complication was caries (35.6%). In the Ls-FDP group, no irreversible complications were caused by caries. For Ls-FDPs, a primary reason for failure was fracture of the FDP (24.0%), which accounted for only 11.1% of failures for Ss-FDPs. Loss of retention occurred in 24.0% of Ls-FDPs and 11.1% of Ss-FDPs. For both groups, an additional group of irreversible complications was created that combined caries and loss of retention because the original reason was difficult to determine. This group accounted for 22.2% of failures in Ss-FDPs and 28.0% of failures in Ls-FDPs. Several authors have reported the frequencies and reasons for failure and estimated the mean life span of FDPs. Walton et al,[16] Foster[35] and Valderhaug[5] concluded that the mean life span with caries as the reason for failure was between 8.4 and 12 years, while the mean life span with loss of retention as the reason for failure was between 4.5 and 9 years. The mean life span of the Ss-FDPs in the present survey was 11.6 years for caries but 9.5 years for loss of retention. In Ls-FDPs, no irreversible complications were attributed to caries, while the mean life span for loss of retention was 5.9 years. The combined retention-caries Ls-FDPs had a mean life span of 6.9 years, which is comparable with the loss of retention group and with the current literature. It is most likely that the largest reason for failures in this combined group is loss of retention. Thus, for the Ls-FDPs, it can be concluded that technical failures accounted for 56.0% to 84.0% of total failures. For Ss-FDPs, the combined group had a mean life span of 9.7 years, which is comparable with the loss of retention group in this survey and the mean life span for caries in the literature, but not comparable with the literature for loss of retention. Therefore, it is likely that the combined failure group is a mixture of loss of retention and caries as primary factors for irreversible complications. For the Ss-FDP group, it can be concluded that biologic failures accounted for 55.6% to 66.7% of failures. The difference between Ss-FDPs and Ls-FDPs is obvious. For Ss-FDPs, 66.7% of irreversible complications were biologic, whereas for Ls-FDPs, 84.0% of irreversible complications were technical.

In previous studies,[23,24] the authors hypothesized that when more abutment teeth are used for an equal replacement of missing teeth (ie, a lower pontic/abutment ratio), the percentage of loss of retention will be higher, sometimes with a low percentage of caries. In these studies, the failure rates for caries and loss of retention were 38.1% and 9.5%, respectively, for FDPs with 3 units in function.[24] For FDPs with 4 units in function (unpublished data), the failure rates for caries and loss of retention were 32.0% and 12.0%, respectively. For FDPs with 3 to 9 units in function (combined with a high pontic/abutment ratio),[23] the failure rates for caries and loss of retention were 22.2% and 15.3%, respectively. In the current study, all Ss-FDPs had only 2 abutments for the replacement of 1 or 2 missing teeth. There were more retainers in function for the Ls-FDPs. The failure rates because of caries for the Ss-FDPs (35.6%) and Ls-FDPs (0.0%) combined with the failures

attributed to loss of retention for Ss-FDPs (11.1% to 22.2%) and Ls-FDPs (24.0% to 52.0%) confirmed this hypothesis. These results correspond with the results of other studies showing caries as the main cause of failure[5,9,10,14,23,24,36–38] and are comparable with those of studies based on FDPs with more abutments in function for the replacement of an equal number of missing teeth,[2–4,6,7] showing loss of retention to be the main cause of failure.

Some authors reported on the mean life span of FDPs in relation to the reason for failure, and the results are in accordance with the results in this study. The mean life span with caries as the reason for failure was 11.6 years, and the mean life span for loss of retention was 7.5 years. The hypothesis that loss of retention is the main cause of failure in prosthetic reconstructions with a low pontic/abutment ratio could elucidate the fact that in these studies caries does not seem to be the major problem, as shown by the longer mean life span with caries.

In the present study, failure was divided into 2 groups: irreversible and reversible complications. In previous studies,[23,24] the occurrence of a reversible complication had a predictive value for future irreversible complications. This was significantly confirmed in this study for both Ss-FDPs and Ls-FDPs. For Ss-FDPs, the mean survival time of the early ($<$ 2 years) reversible complication group was 9.0 years, while the mean survival time of the late ($>$ 2 years) reversible complication group was 14.9 years. This result was statistically significant ($P = .007$), confirming that occurrence of a reversible complication within the first 2 years will lead to an irreversible complication. For Ls-FDPs, on the other hand, the mean survival time of the early ($<$ 2 years) reversible complication group was 11.8 years, while the mean survival time of the late ($>$ 2 years) reversible complication group was 13.5 years. This outcome was not statistically significant ($P = .466$). Statistically, the results were extracted to a cutoff point of 5 years for reversible complications in the Ls-FDPs. This newly conceived value rendered a statistically significant result ($P = .039$). It is the authors' view that the survival of complete crowns,[34] 3-unit FDPs,[24] 4-unit FDPs, and $\geq$ 5-unit FDPs should be investigated separately. In this respect, it should be considered that fewer failures occurred in the Ss-FDPs group; however, the mean survival time seems to be longer in the Ls-FDP group. Further investigation is needed to precisely identify whether there exists a statistical cutoff point for all groups.

Conclusions

The survival of Ss-FDPs (70.8%) and Ls-FDPs (52.8%) over a 20-year period is favorable. A statistically significant difference ($P = .030$) was found between the survival of Ss-FDPs and Ls-FDPs. There was no statistically significant difference between the Ss-FDPs and Ls-FDPs regarding survival for the vital groups ($P = .186$) and RCT groups ($P = .126$). For Ss-FDPs, there was a statistically significant difference overall between the vital and RCT groups ($P = .009$). The use of an RCT abutment was significantly more prone to failure in both Ss-FDPs and Ls-FDPs, and this tendency became more significant in FDPs with $\geq$ 4 units. Caries, fracture of the framework, and loss of retention were the main reasons for failure. An obvious difference in the main reason for irreversible failure was noted between Ss-FDPs and Ls-FDPs. More abutments in function will increase the risk of loss of retention and sometimes loss of the FDP. Occurrence of a reversible complication has a predictive value for an irreversible complication later on. Concerning Ss-FDPs, a reversible complication within the first 2 years will lead to an irreversible complication.

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Literature Abstract

Crown-to-implant ratios of single tooth implant-supported restorations

The purpose of this study was to investigate the crown-implant ratios of implant-supported single tooth restorations. The study cohort was composed of 889 single-tooth implants from 294 subjects with 1 or more single-tooth implants (Bicon) placed between 1992 and 2004. A retrospective chart review was conducted. The length of the crown and implant were measured from the radiographs to calculate the crown-to-implant ratio. Measurements were taken to within 0.1 mm under magnification. Removal of implant for any reason was considered clinical failure. Data were reported in descriptive statistics. The results indicated that: *(1)* the mean (SD) follow-up time was 2.3 (1.7) years, with a range of 0.1 to 7.4 years; *(2)* 16 failures were noted, resulting in a success rate of 98.2%; *(3)* the crown-implant ratios ranged from 0.5:1 to 3:1, and the mean (SD) crown-implant ratio of implants in function was 1.3:1 (0.34); *(4)* the mean crown-to-implant ratio of failed implants was 1.4:1 (2.5). The authors concluded that the crown-to-implant ratios of implants in function were similar to those of implants that failed. The conventional concept of crown-root ratios for natural abutment teeth may not be applicable in implant-supported crowns.

Schulte J, Flores AM, Weed M. *J Prosthet Dent* 2007;98:1–5. **Reference**: 20. **Reprints**: Dr John Schulte, Department of Restorative Sciences, University of Minnesota, School of Dentistry, 515 Delaware Street SE, Minneapolis, MN 55455. Fax: 612 626 2655—*Ansgar C. Cheng, Singapore*