A Meta-Analysis of Prosthodontic Complication Rates of Implant-Supported Fixed Dental Prostheses in Edentulous Patients After an Observation Period of at Least 5 Years

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Purpose: *To systematically review clinical studies on prosthodontic complication rates of implant fixed dental prostheses in edentulous patients after an observation period of at least 5 years.* ***Materials and Methods:*** *A literature search was conducted using different electronic databases. Specific terms were used for the database search, which spanned the years 1990 to 2008. The search was augmented by using the option of "related articles" as well as by hand searching of references and relevant journals. Relevant studies were selected according to predetermined inclusion and exclusion criteria. Agreement between reviewers was determined by using Cohen kappa coefficients.* ***Results:*** *The initial database search yielded 8,216 relevant titles. Following the filtering process, 19 studies were finally selected. No study directly compared the incidence of prosthodontic complications of complete implant-supported metal-ceramic versus metal–acrylic resin fixed prostheses in the completely edentulous patient. Studies of metal-ceramic prostheses were scarce and short term.* ***Conclusion:*** *Metal–acrylic resin complete implant fixed prostheses presented with various prosthodontic complications after long-term function. The most frequent complications were veneer fracture and material wear.* Int J Oral Maxillofac Implants 2011;26:304–318

Key words: *edentulous arch, implant fixed prosthesis, meta-analysis, prosthodontic complications, screw, veneer*

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The main objective in the treatment of edentulous patients with osseointegrated implants is either to avoid removable complete dentures by placement of complete implant-supported fixed prostheses (IFDPs) or to improve the retention and stability of removable complete dentures.[1] The earliest implant studies[2–8] followed patients treated with metal–acrylic resin complete IFDPs[9] with distal cantilevers, principally in the mandible. These restorations consisted of denture teeth connected to a metal framework with acrylic resin and were attached with screws to six implants placed between the mental foramina. The same prosthetic design is being used today on four to six implants in the mandible.[1]

As implant dentistry evolved, a variety of prosthetic designs associated with implant prostheses was introduced. In addition, the number of patients asking for implant-supported reconstructions has increased considerably over the past few years,[10] and many patients receiving implants are now treated with metal-ceramic complete IFDPs.[9] A metal-ceramic IFDP consists of a ceramic layer bonded to a cast metal framework that can be cemented to transmucosal abutments or secured with prosthetic retention screws.[11]

Clinical research has mainly focused either on implant survival or on biologic and technical complications in partial edentulism.[12–20] The incidence of prosthodontic complications of complete IFDPs in the edentulous arch has been addressed to only a minor extent. No comparisons have been made between the incidence of prosthodontic complications of metal-ceramic versus metal–acrylic resin IFDPs.

The purpose of this study was to systematically review clinical studies of prosthodontic complication rates of IFDPs in edentulous patients after an observation period of at least 5 years.

METHODS AND MATERIALS

Search Strategy

The literature search was conducted by two individuals (TB, HP) using different electronic databases (MEDLINE/PubMed, the Cochrane Register of Randomized Controlled Trials, and the Database of Abstracts of Reviews of Effects) for English-language clinical studies reporting on prosthodontic complications of metal-ceramic and metal-resin IFDPs in the edentulous arch. Prosthodontic complications included framework/veneering material fractures, loosening of the prosthetic screw and/or abutment screw, fracture of the prosthetic screw and/or abutment screw, esthetic deficiencies, and material wear. The search terms that were used, alone or in combination, were "implant fixed prostheses," "prosthodontic complications," "technical complications," "mechanical complications," "screw complications," "edentulous arch," "metal framework fracture," "acrylic veneer fracture," "ceramic veneer fracture," "edentulous mandible," and "edentulous maxilla." The search covered a time span between January 1990 and December 2008. The option of "related articles" was also used. Review articles, as well as references from different studies, were also used to identify relevant articles. Hand searching for the time span between January 1990 and December 2008 was conducted on the following journals: *Journal of Prosthetic Dentistry, International Journal of Prosthodontics, International Journal of Oral & Maxillofacial Implants, Implant Dentistry,* and *Clinical Oral Implants Research.*

Selection of Studies

The review process consisted of two phases. During the first phase, the titles, abstracts, and/or full texts were reviewed by the two reviewers together. Initially, titles were screened for relevance, and the abstracts of the relevant articles were obtained. The articles obtained were screened using the following exclusion and inclusion criteria. Articles that were laboratory studies, case reports, technical articles, or were in a language other than English or had no English-language abstract were excluded. Clinical studies reporting on prosthodontic complications of IFDPs in the edentulous arch, with either a prospective or a retrospective design and patient follow-up, were included.

Any disagreement was resolved by discussion; in case of doubt, the full text of the article was obtained. Hand searching of the selected journals, as well as searching of the references of the selected studies, was also implemented at this point.

The selected full texts were further screened independently by the two reviewers in a second phase of review using the following inclusion criteria:

1. Mean follow-up period of at least 5 years
2. Clinical examination of patients at the follow-up visit
3. Details reported on the materials used for the prosthetic reconstruction
4. Number of patients stated
5. Study outcome stated as prosthodontic complications and related to follow-up time

Various potential factors influencing complications that were examined were:

1. Presence of parafunctional habits
2. Number of implants supporting the IFDPs
3. Opposing arch condition
4. Type of suprastructure retention (screw versus cement)

Interreviewer agreement was determined using Cohen kappa coefficients.

Next, the final included studies that passed the second phase in the review process were classified according to the strength of evidence into four categories according to Jökstad et al[21]:

1. A1: controlled clinical trial with patient randomization (RCT)
2. A2: controlled clinical trial with split-mouth randomization (split-mouth RCT)
3. B: prospective controlled trial without randomization (CCT)
4. C: clinical studies with different designs than categories A and B (retrospective, case series, etc)

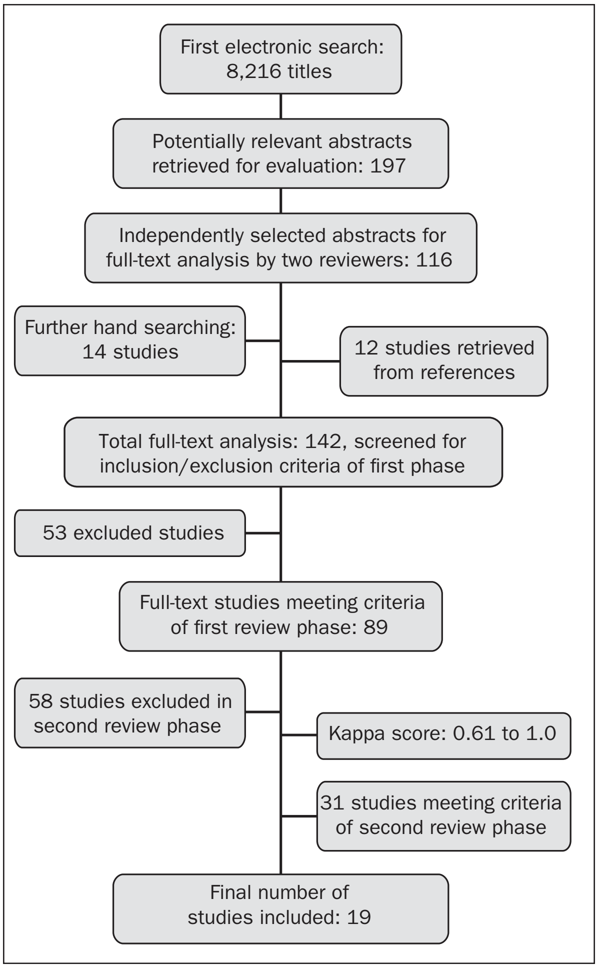

Fig 1 Search strategy.

Data Extraction

Data of the final studies were tabulated for the following prosthodontic complications: veneer fracture, loosening of the prosthetic screw and/or abutment screw, fracture of the prosthetic screw and/or abutment screw, framework fracture, esthetic deficiencies, and material wear. The incidence of each prosthodontic complication mentioned earlier was finally calculated in relation to time. In studies where only the minimum follow-up time was mentioned, that interval was used to measure the total exposure time of the restorations. In cases of multiple publications following the same cohort of patients, the study with the longest follow-up was included.

Statistical Analysis

Complication rates for IFDPs were calculated by dividing the total number of events (complications) in the numerator by the total IFDPs' exposure time in years in the denominator. The total number of events (numerator) was extracted directly from the publication. The exposure time (denominator) was calculated by multiplying the mean follow-up time by the number of IFDPs available for statistical analysis. The mean follow-up was extracted directly from the articles. IFDPs available for the analysis were defined as all the prostheses from which information was available relative to the issues considered.

Poisson distribution was considered for the number of events per variable under examination. Five-, 10-, and 15-year survival proportions (with the corresponding 95% confidence intervals [CIs]) were calculated via the relationship between the event rate and the survival function $S(t) = \exp(-t \times \text{event rate})$, assuming a constant event rate. The 95% CI was calculated with the aid of Poisson regression analysis with a logarithmic link function. It should be mentioned that Poisson regression is appropriate for rate data, where the rate is a count of events occurring to a unit of observations divided by a measure of exposure (events per unit time). If heterogeneity (I^2 value with $P < .05$) among papers' estimates per variable was observed, a random effect model was considered for the summary estimates. STATA software (Statacorp) was used for Poisson regression.

RESULTS

Figure 1 shows the process used to identify the studies finally included from the initial yield of 8,216 titles. Initial analysis of titles led to 197 abstracts. Seventy-nine abstracts were excluded, so 116 full texts were obtained. Twenty-six studies were retrieved from journal hand searching and references; therefore, 142 full texts were screened for inclusion/exclusion criteria in the first phase. Of these, 53 studies were excluded and 89 studies passed the first review phase.

In the second review phase, 58 studies[22–79] were excluded and 31 studies[4–8,80–104] were deemed to have met the inclusion criteria. After studies of the same cohorts were excluded, 19 studies[80–98] were finally selected for analysis. The interreviewer agreement for the five inclusion criteria during the second review phase ranged from "substantial" to "perfect" (kappa: 0.61 to 1.0; $P < .001$). The studies that were rejected during the second review phase are shown in Table 1.

All selected studies[80–98] had been published in the last 18 years. The publication dates ranged from 1990 to 2008, with half of the studies published in the last 10 years. No study directly compared the incidence of prosthodontic complications of metal-ceramic versus metal–acrylic resin IFDPs in completely edentulous patients. Almost half of the studies were classified as

Table 1 Studies Excluded During the Second Phase of Review and Reasons for Exclusion

Studies	Reason for exclusion
Köndell et al, 1988[22]; Jemt, 1991[23]; Arvidson et al, 1992[24]; Tolman and Laney, 1992[25]; Jemt and Linden, 1992[26]; Naert et al, 1992[27]; Walton and MacEntee, 1993[28]; Carlson and Carlsson, 1994[29]; Hulterström and Nilsson, 1994[30]; Gunne et al, 1995[31]; Rubenstein, 1995[32]; Walton and MacEntee, 1997[33]; Behr et al, 1998[34]; Kaptein et al, 1999[35]; Krekmanov et al, 2000[36]; Örtorp and Jemt, 2000[37]; Zitzmann and Marinello, 2000[38]; De Bruyn et al, 2000[39]; Yi et al, 2001[40]; Moberg et al, 2001[41]; Engquist et al, 2002[42]; Örtorp and Jemt, 2002[43]; Duncan et al, 2003[44]; Henry et al, 2003[45]; Raghoebar et al, 2003[46]; Maló et al, 2003[47]; Göthberg et al, 2003[48]; Engstrand et al, 2003[49]; Bergkvist et al, 2004[50]; Romeo et al, 2004[51]; Preiskel and Tsolka, 2004[52]; Friberg et al, 2005[53]; Hjalmarsson and Smedberg, 2005[54]; Maló et al, 2006[55]; Aparicio et al, 2006[56]	Mean follow-up period < 5 y
De Bruyn et al, 1999[57]; Hellden et al, 2003[58]; Rasmusson et al, 2005[59]; Åstrand at el, 2004[60]	Details on materials not reported
Brånemark et al, 1995[61]; Keller, 1995[62]; Schnitman et al, 1997[63]; Eliasson et al, 2000[64]; Wennerberg et al, 2001[65]; Peñarrocha et al, 2007a[66]	Prosthodontic complications not stated
Brånemark et al, 1999[67]; Collaert and De Bruyn, 2002[68]; Peñarrocha et al, 2007b[69]	Mean follow-up period < 5 y; Prosthodontic complications not stated
Tolman and Laney, 1993[70]; Allen et al, 1997[71]; Balshi et al, 1997[72]	Mean follow-up period < 5 y; Details on materials not reported
Shackleton et al, 1996[73]; Misch and Wang, 2003[74]	Mean follow-up period < 5 y; Details on materials not reported; Prosthodontic complications not stated
De Bruyn et al, 1997[75]	Mean follow-up period < 5 y; No clinical examination at follow-up visit
Keller et al, 1999[76]; Friberg et al, 2000[77]; Hedkvist et al, 2004[78]; Nelson et al, 2007[79]	Details on materials not reported; Prosthodontic complications not stated

category C and seven were category A1 according to the strength of the evidence,[21] and most were implemented in a university setting. The studies included a total of 944 patients with an age range of 28 to 93 years. The demographics and designs of the included studies are depicted in Table 2.

The studies reported on various commercially available implant systems. Most studies used an external-connection implant system (Nobel Biocare), and only four used an internal-connection implant system. No studies of metal-ceramic IFDPs fulfilled the criteria for inclusion in the analysis. All the finally included studies, therefore, reported on complications with screw-retained metal–acrylic resin IFDPs. A total of 998 IFDPs was observed over a minimum period of 5 years up to a maximum period of 23 years. The mean observation times ranged between 5 and 21.4 years. The majority of IFDPs were placed in the mandible. The information on the IFDPs placed is presented in Table 3.

All the prosthodontic complications related to suprastructure components are presented in Tables 4 to 11. Veneer fractures represented the most frequent prosthodontic complication; they were reported in 14 of the 19 included studies. The statistical analysis revealed estimated cumulative rates of veneer fractures over an observation period of 5, 10, and 15 years of 30.6%, 51.9%, and 66.6%, respectively (Table 4). The estimated rates of abutment and prosthetic screw loosening after 15 years were 13.4% and 15%, respectively (Tables 5 and 7). The estimated rates of abutment and prosthetic screw fracture after 15 years were 6.3% and 11.7%, respectively (Tables 6 and 8). The estimated rates for framework fractures, material wear, and esthetic deficiencies during the same follow-up period were 8.8%, 43.5%, and 9%, respectively (Tables 9 to 11).

The analysis of various factors potentially influencing complications did not produce any results. The final papers did not include any cement-retained IFDPs, and the presence of parafunctional habits was not considered. The number of implants supporting the IFDPs was fairly uniform throughout the studies and typically ranged from four to six. As for the potential effect of the condition of the opposing arch, only one study[90] reported weak evidence that more maintenance was needed for patients with an opposing IFDP.

Table 2 Study Design and Demographics of Included Studies

Study	Category of evidence (study design)	Gender		No. of patients			Age (y)			Setting
		M	F	Planned	Actual	% dropouts	Range	Mean	SD	
Johansson and Palmqvist, 1990[80]	C (R)	22	25	47	47	0	NR	NR	NR	University
Kallus and Bessing, 1994[81]	C (R)	14	36	50	50	0	NR	66.1 (M) 68.2 (F)	NR	Private
Henry et al, 1995[82]	C (P)	NR	NR	15	15	0	29–73	50	NR	University
Watson and Davis, 1996[83]	B (P)	NR	NR	20	NR	NR	NR	NR	NR	University
Friberg et al, 1997[84]	A2 (P)	49	54	102	83	18.6	33–83	59	NR	University
Makkonen et al, 1997[85]	C (P)	6	7	13	10	23.1	39–69	50	10	University
Arvidson et al, 1998[86]	A1 (P)	43	64	107	91	15	NR	NR	NR	NR
Tinsley et al, 2001[87]	A1 (P)	NR	NR	21	NR	NR	37–80	NR	NR	NR
Jemt et al, 2002[88]	A1 (P)	33	25	58	50	13.8	38–74	60	NR	Private
Murphy et al, 2002[89]	B (P)	18	8	26	26	0	NR	60	NR	University
Davis et al, 2003[90]	C (R)	8	29	37	37	0	36–71	56	NR	NR
Ekelund et al, 2003[91]	C (P)	14	33	47	30	36.2	34–67	53.4	NR	University
Attard and Zarb, 2004[92]	A1 (P)	10	36	46	31	32.6	28–69	50	11,6	University
Engfors et al, 2004[93]	C (R)	112	136	248	164	33.9	41–93	Study group 83.1; control group 65	Study group 2.9; control group 9.6	Private
Örtorp and Jemt, 2004[94]	A1 (P)	62	64	126	101	19.8	41–88	66.5	10.8	Private
Jemt and Johansson, 2006[95]	C (P)	48	28	76	28	63.2	32–75	60.1	11.6	University
Örtorp and Jemt, 2006[96]	A1 (P)	104	104	208	112	46.2	35–87	NR	NR	Private
Fischer et al, 2008[97]	A1 (P)	8	16	24	23	4.2	NR	64	NR	University
Purcell et al 2008[98]	C (R)	14	32	46	46	0.0%	NR	59	NR	NR

NR = not reported; R = retrospective; P = prospective.

DISCUSSION

Systematic reviews differ from other types of reviews in that they adhere to a strict scientific protocol to make them more comprehensive, to eliminate the likelihood of bias, and to provide more reliable results upon which to draw conclusions and make decisions. Rather than reflecting the views of the authors or being based on only a (possibly biased) selection of the published literature, they represent a comprehensive summary of the available evidence, with strict inclusion and exclusion criteria. Methodologies for undertaking systematic reviews have been described.[105,106] The gold standard for systematic reviews is to include RCTs, which are more likely to provide reliable information than other sources of evidence. The majority of the studies included in this review were prospective. Almost half of the studies were classified as category C and seven as A1 (RCTs).

Two reviewers were used to ensure that the selection of studies for inclusion and data extraction could be performed independently and to increase the chance that errors would be detected. Interexaminer

Table 3 Information on IFDPs in the Selected Studies

Study	Implant system	Type of connection	Planned no. of implants per prosthesis	Type of prosthesis	Opposing dentition	No. of max prostheses			No. of mand prostheses			Total no. of prostheses			Follow-up (y)	
						Planned	Actual	% dropout	Planned	Actual	% dropout	Planned	Actual	% dropout	Range	Mean
Johansson and Palmqvist, 1990[80]	Nobel Biocare	External	NR	MR	NR	18	18	0	31	31	0	49	49	0	3–9	5.2
Kallus and Bessing, 1994[81]	Nobel Biocare	External	4–6	MR	NR	16	16	0	34	34	0	50	50	0	5.5–5.9	5.4
Henry et al, 1995[82]	Nobel Biocare	External	6	MR	12 CD	NA	NA	NA	15	15	0	15	15	0	NA	10
Watson and Davis, 1996[83]	Nobel Biocare	External	4–6	MR	CD	NA	NA	NA	20	20	0	20	20	0	NA	5
Friberg et al, 1997[84]	Nobel Biocare	External	NR	MR	NR	33	NR	NR	69	NR	NR	102	83	18.6	NA	5
Makkonen et al, 1997[85]	Astra	Internal	5–6	MR	CD	NA	NA	NA	13	10	23.1	13	10	23.1	NA	5
Arvidson et al, 1998[86]	Astra	Internal	4–6	MR	NR	NA	NA	NA	107	91	15.0	107	91	15.0	NA	5
Tinsley et al, 2001[87]	Calcitek	External	5	MR	16 CD, 5 other	NA	NA	NA	21	21	0	21	21	0	NA	5
Jemt et al, 2002[88]	Nobel Biocare	External	> 5	MR	NR	58	50	13.8	NA	NA	NA	58	50	13.8	NA	5
Murphy et al, 2002[89]	Astra	Internal	5	MR	CD	NA	NA	NA	26	26	0	26	26	0	NA	5
Davis et al, 2003[90]	Nobel Biocare	External	5–6	MR	22 CD, 6 IP, 9 ND	8	8	0	29	29	0	37	37	0	NA	5
Ekelund et al, 2003[91]	Nobel Biocare	External	5–6	MR	13 IP, 34 CD	NA	NA	NA	47	30	36.2	47	30	36.2	20–23	21.4
Attard and Zarb, 2004[92]	Nobel-Biocare	External	4–6	MR	40 CD, 3 ND	4	NR	NR	41	NR	NR	45	38	15.6	11–15	11
Engfors et al, 2004[93]	Nobel Biocare	External	4–8 max/ 4–6 mand	MR	NR	95	64	32.6	162	103	36.4	257	167	35	NA	5
Örtorp and Jemt, 2004[94]	Nobel Biocare	External	4–8 max/ 4–6 mand	MR	41 CD, 25 IP, 63 M	54	40	25.9	75	61	18.6	129	101	21.7	NA	5
Jemt and Johansson, 2006[95]	Nobel Biocare	External	6 mean	MR	1 CD, 9 RPD, 18 IP	76	28	63.2	NA	NA	NA	76	28	63.2	NA	15
Örtorp and Jemt, 2006[96]	Nobel Biocare	External	4–6	MR	154 CD, 14 IP, 40 M	NA	NA	NA	208	112	46.2	208	112	46.2	NA	10
Fischer et al, 2008[97]	Straumann	Internal	5–6	MR	1 CD, 6 RPD, 1 IP, 8 ND, 6 M	24	23	4.2	NA	NA	NA	24	23	4.2	NA	5
Purcell et al 2008[98]	Nobel Biocare	External	5–6	MR	CD	NA	NA	NA	46	46	0	46	46	0	5–9.7	7.9

NR = not reported; NA = not applicable; MC = metal-ceramic; MR = metal–acrylic resin; CD = complete denture; RPD = removable partial denture; IP = implant prosthesis; ND = natural dentition; M = mixed; max = maxilla; mand = mandible.

Table 4 Veneer Fracture

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of veneer fracture events	Estimated rate*
Johansson and Palmqvist, 1990[80]	49	5.2	254.8	11	4.3
Henry et al, 1995[82]	15	10	150	23	15.3
Watson and Davis, 1996[83]	20	5	100	4	4.0
Friberg et al, 1997[84]	83	5	415	7	1.7
Jemt et al, 2002[88]	50	5	250	23	9.2
Murphy et al, 2002[89]	26	5	130	4	3.1
Davis et al, 2003[90]	37	5	185	60	32.4
Ekelund et al, 2003[91]	30	21.4	642	5	0.8
Engfors et al, 2004[93]	167	5	835	33	3.9
Örtorp and Jemt, 2004[94]	101	5	505	38	7.5
Jemt and Johansson, 2006[95]	28	15	420	158	37.6
Ortorp and Jemt, 2006[96]	112	10	1,120	53	4.7
Fischer et al, 2008[97]	23	5	115	30	26.1
Purcell et al, 2008[98]	46	7.9	363.4	28	7.7

Summary estimates†	Rate (%)	95% CI
Based on random effect	7.3	3.9–13.3
Cumulative 5-y complication rates	30.6	17.7–48.6
Cumulative 10-y complication rates	51.9	32.3–75.5
Cumulative 15-y complication rates	66.6%	44.3–86.4

*Per 100 prostheses-years.
†Heterogeneity: $I^2 = 97.443$; $P < .001$.

Table 5 Abutment Screw Loosening

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of abutment screw loosening events	Estimated rate*
Kallus and Bessing, 1994[81]	50	5.4	270	10	3.7
Watson and Davis, 1996[83]	20	5	100	6	6.0
Arvidson et al, 1998[86]	91	5	455	0	0
Tinsley et al, 2001[87]	21	5	105	0	0
Murphy et al, 2002[89]	26	5	130	2	1.5
Davis et al, 2003[90]	37	5	185	4	2.2
Engfors et al, 2004[93]	167	5	835	1	0.1
Ortorp and Jemt, 2004[94]	101	5	515	0	0
Jemt and Johansson, 2006[95]	28	15	420	0	0
Ortorp and Jemt, 2006[96]	112	10	1,120	53	4.7
Purcell et al, 2008[98]	46	7.9	363.4	5	1.4

Summary estimates†	Rate	95% CI
Based on random effects	1.0	0.5–1.5
Cumulative 5-y complication rates	4.7	2.3–7.1
Cumulative 10-y complication rates	9.2	4.5–13.7
Cumulative 15-y complication rates	13.4	6.6–19.8

*Per 100 prostheses-years. †Heterogeneity: $I^2 = 86.345$; $P < .001$.

Table 6 Abutment Screw Fracture

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of abutment screw fracture events	Estimated rate*
Johansson and Palmqvist, 1990[80]	49	5.2	254.8	3	1.2
Kallus and Bessing, 1994[81]	50	5.4	270	0	0
Henry et al, 1995[82]	15	10	150	8	5.3
Watson and Davis, 1996[83]	20	5	100	5	5.0
Friberg et al, 1997[84]	83	5	415	1	0.2
Arvidson et al, 1998[86]	91	5	455	0	0
Tinsley et al, 2001[87]	21	5	105	2	1.9
Jemt et al, 2002[88]	50	5	250	0	0
Murphy et al, 2002[89]	26	5	130	1	0.8
Davis et al, 2003[90]	37	5	185	8	4.3
Attard and Zarb, 2004[92]	38	11	418	25	6.0
Engfors et al, 2004[93]	167	5	835	1	0.1
Ortorp and Jemt, 2004[94]	101	5	505	0	0
Jemt and Johansson, 2006[95]	28	15	420	0	0
Ortorp and Jemt, 2006[96]	112	10	1,120	6	0.5
Fischer et al, 2008[97]	23	5	115	0	0
Purcell et al, 2008[98]	46	7.9	363.4	2	0.5

Summary estimates†	Rate	95% CI
Based on random effects	0.4	0.2–0.7
Cumulative 5-y complication rates	2.1	0.8–3.5
Cumulative 10-y complication rates	4.3	1.6–6.8
Cumulative 15-y complication rates	6.3	2.4–10.1

*Per 100 prostheses-years. †Heterogeneity: $I^2 = 68.992$; $P < .001$.

agreement ranged from substantial to perfect. Database searches were also augmented by hand searching to minimize selection bias.[107]

The exclusion of papers in languages other than English may have resulted in the loss of some papers and poses a disadvantage for two reasons: *(1)* the number of abstracts actually examined might have been limited if there were a substantial number of additional studies published in languages other than English; *(2)* the chance of bias may have been increased if the results of studies published in English differed systematically from those published in other languages. On the other hand, it is difficult to gain access to nonEnglish-language journals all over the world, and it is difficult to define the features of the peer-review processes of these journals. Moreover, when nonEnglish papers are selected, based on their abstracts, the contents must be translated, with the risk of interpretation problems.[108] One study[109] found little effect of the inclusion/exclusion of papers published in languages other than English on combined effect estimates in meta-analyses of RCTs.

No studies existed that directly compared the incidence of prosthodontic complications of metal-ceramic versus metal–acrylic resin complete IFDPs. Therefore, all the studies included in the present review examined metal–acrylic resin IFDPs. There were no studies following metal-ceramic IFDPs that also met the inclusion criteria of the second review phase and especially the mean follow-up period: nine studies[27,29,33,35,38,39,50,51,56] reported on metal-ceramic IFDPs but had a mean follow-up period between 1 and 3 years. This was an unexpected finding because metal-ceramic implant prostheses are now routinely used for the rehabilitation of both partially and completely edentulous patients.[1] This finding also warrants caution regarding the long-term rate of complications of metal-ceramic IFDPs. The follow-up time chosen was set at a minimum of 5 years, which could be considered adequate for at least short-term results. The mean follow-up times reported in the final studies permitted a long-term projection of complication rates up to 15 years of follow-up.

Technical complications are common in all forms of prosthetic dentistry[18,110] and often jeopardize the

Table 7 Prosthetic Screw Loosening

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of prosthetic screw loosening events	Estimated rate*
Kallus and Bessing, 1994[81]	50	5.4	270	67	24.8
Watson and Davis, 1996[83]	20	5	100	1	1.0
Makkonen et al, 1997[85]	10	5	50	1	2.0
Arvidson et al, 1998[86]	91	5	455	0	0
Tinsley et al, 2001[87]	21	5	105	0	0
Jemt et al, 2002[88]	50	5	250	6	2.4
Murphy et al, 2002[89]	26	5	130	15	11.5
Davis et al, 2003[90]	37	5	185	3	1.6
Ekelund et al, 2003[91]	30	21.4	642	25	3.9
Engfors et al, 2004[93]	167	5	835	1	0.1
Ortorp and Jemt, 2004[94]	101	5	505	0	0
Jemt and Johansson, 2006[95]	28	15	420	0	0
Ortorp and Jemt, 2006[96]	112	10	1,120	2	0.2
Fischer et al, 2008[97]	23	5	115	2	1.7
Purcell et al, 2008[98]	46	7.9	363.4	13	3.6

Summary estimates†	Rate	95% CI
Based on random effects	1.1	0.6–1.6
Cumulative 5-y complication rates	5.3	2.8–7.7
Cumulative 10-y complication rates	10.3	5.6–14.8
Cumulative 15-y complication rates	15.0	8.2–21.3

*Per 100 prostheses-years. †Heterogeneity: $I^2 = 88.936$; $P < .001$.

function and/or esthetics of a given prosthesis. Metal–acrylic resin IFDPs presented with a varying frequency of different complications, with veneer fracture being the most frequent. Almost 70% of the prostheses presented with some form of veneer fracture after 15 years of service. Acrylic resin veneers require sufficient material thickness and support from their underlying frameworks to withstand forces in the oral cavity.[111–114] Veneer fractures may be caused by material failure, design issues, and/or technical errors.[113] Many of these factors can be controlled with technical excellence, but the high incidence of acrylic resin failures in prosthodontics[18,110] suggests that the problem cannot be eliminated completely. The incidence of veneer fracture versus the number of prostheses reviewed indicates that certain prostheses[82,90,94,95,97] presented with multiple veneer fractures, thereby confirming the role of technical errors as mentioned before. The inherent weakness of acrylic resin denture teeth was also evident in the frequency of wear. Almost half of the metal–acrylic resin IFDPs presented with material wear after 15 years. Different options were presented to slow the process of tooth wear, including altering the denture tooth surface with amalgam or gold alloy or using porcelain denture teeth.[98] The frequency of both acrylic resin fractures and wear is influenced by such factors as the opposing dentition and the presence of parafunctional habits.[115,116] The effects of these factors were not considered in the results of the final papers in this review. The design of future studies should incorporate these variables. When acrylic resin veneer fractures or wear occur, the ability to remove and repair the prosthesis, as is the case with screw-retained metal–acrylic resin IFDPs, is a distinct advantage. However, the high frequency of these particular complications indicates the need to inform prospective implant patients of future maintenance requirements.

Screw-related complications are commonly reported in the dental literature.[18,20,44,117] Regardless of their design, implant screw joints are susceptible to screw loosening or fracture because of the magnitude and direction of oral forces and the strength limitations of the components. Various factors may contribute to screw complications: inadequate preload on the screws, overtightening of the screws leading to

Table 8 Prosthetic Screw Fracture

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of prosthetic screw fracture events	Estimated rate*
Johansson and Palmqvist, 1990[80]	49	5.2	254.8	1	0.4
Henry et al, 1995[82]	15	10	150	2	1.3
Arvidson et al, 1998[86]	91	5	455	0	0
Tinsley et al, 2001[87]	21	5	105	0	0
Jemt et al, 2002[88]	50	5	250	0	0
Murphy et al, 2002[89]	26	5	130	2	1.5
Davis et al, 2003[90]	37	5	185	4	2.2
Ekelund et al, 2003[91]	30	21.4	642	2	0.3
Attard and Zarb, 2004[92]	38	11	418	78	18.7
Ortorp and Jemt, 2004[94]	101	5	505	0	0
Jemt and Johansson, 2006[95]	28	15	420	1	0.2
Fischer et al, 2008[97]	23	5	115	0	0
Purcell et al, 2008[98]	46	7.9	363.4	8	2.2

Summary estimates†	Rate	95% CI
Based on random effects	0.8	0.3–1.4
Cumulative 5-y complication rates	4.1	1.5–6.6
Cumulative 10-y complication rates	8.0	2.9–12.7
Cumulative 15-y complication rates	11.7	4.4–18.5

*Per 100 prostheses-years. Heterogeneity: $I^2 = 86.739$; $P < .001$.

Table 9 Framework Fracture

Study	No. of prostheses	Mean follow- up (y)	Total exposure time (y)	No. of framework fracture events	Estimated rate*
Johansson and Palmqvist, 1990[80]	49	5.2	254.8	1	0.4
Friberg et al, 1997[84]	83	5	415	1	0.2
Makkonen et al, 1997[85]	10	5	50	1	2.0
Arvidson et al, 1998[86]	91	5	455	0	0
Tinsley et al, 2001[87]	21	5	105	1	0.9
Murphy et al, 2002[89]	26	5	130	0	0
Davis et al, 2003[90]	37	5	185	7	3.8
Attard and Zarb, 2004[92]	38	11	418	16	3.8
Engfors et al, 2004[93]	167	5	835	2	0.2
Ortorp and Jemt, 2004[94]	101	5	505	2	0.4
Jemt and Johansson, 2006[95]	28	15	420	1	0.2
Ortorp and Jemt, 2006[96]	112	10	1,120	32	2.9
Fischer et al, 2008[97]	23	5	115	0	0
Purcell et al, 2008[98]	46	7.9	363.4	0	0

Summary estimates†	Rate	95% CI
Based on random effects	0.6	0.3–1.0
Cumulative 5-y complication rates	3.0	1.3–4.7
Cumulative 10-y complication rates	6.0	2.6–9.3
Cumulative 15-y complication rates	8.8	3.8–13.6

*Per 100 prostheses-years. †Heterogeneity: $I^2 = 73.456$; $P < .001$.

Table 10 Esthetic Deficiencies

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of esthetic deficiencies events	Estimated rate*
Henry et al, 1995[82]	15	10	150	1	0.7
Ekelund et al, 2003[91]	30	21.4	642	3	0.5
Engfors et al, 2004[93]	167	5	835	7	0.8

Summary estimates†	Rate	95% CI
Based on fixed effects	0.6	0.2–1.0
Cumulative 5-y complication rates	3.1	1.2–5.0
Cumulative 10-y complication rates	6.1	2.4–9.7
Cumulative 15-y complication rates	9.0	3.6–14.1

*Per 100 prostheses-years. †Heterogeneity: $I^2 = 0.000$; $P = .278$

Table 11 Material Wear

Study	No. of prostheses	Mean follow-up (y)	Total exposure time (y)	No. of material wear events	Estimated rate*
Johansson and Palmqvist, 1990[80]	49	5.2	254.8	3	1.2
Henry et al, 1995[82]	15	10	150	1	0.7
Tinsley et al, 2001[87]	21	5	105	2	1.9
Murphy et al, 2002[89]	26	5	130	26	20.0
Jemt and Johansson, 2006[95]	28	15	420	16	3.8
Purcell et al, 2008[98]	46	7.9	363.4	24	6.6

Summary estimates†	Rate	95% CI
Based on random effects	3.8	1.5–9.1
Cumulative 5-y complication rates	17.3	7.4–36.7
Cumulative 10-y complication rates	31.6	14.2–59.9
Cumulative 15-y complication rates	43.5	20.5–74.6

*Based on 100 prostheses-years. †Heterogeneity: $I^2 = 91.029$; $P < .001$.

stripping and/or screw deformation, and/or occlusal overload from parafunction, occlusal interferences, or excessively long cantilevers.[118,119] In the present review, screw-related complications were rare in the majority of studies. Certain studies presented with a higher frequency of screw-related complications, thereby raising the total summary estimate. Abutment screw loosening and abutment screw fracture events were low, with the exception of three[81,83,96] and four[82,83,90,92] publications, respectively. The same held true for prosthetic screw loosening and fracture, where three studies[81,89,92] presented with a higher frequency of complications. The studies with the higher frequency of screw-related complications used an external-hex connection between the dental implants and prosthetic parts. Some of the authors[81,89] mentioned that hand-tightening was used instead of a calibrated torque instrument.

Fracture of the metal framework is a nonreversible complication that usually leads to a remake of the prosthesis. Framework fractures were present to only a minor extent in the majority of the studies in the present systematic review. However, four studies[85,90,92,96] reported relatively higher frequencies of framework fractures during the follow-up period. These four studies[85,90,92,96] described a number of reasons for the occurrence of framework fractures; the most common cited reasons were poor alloy choice and decreased cross-sectional dimension distal to the most posterior implant.[92] Most fractures occurred at the beginning of the cantilever arms.[90] Thus, it can be concluded that the cantilever arms should be kept as short as possible and the bulk of the framework increased around the last abutment. Special attention should be given to the selection of the alloy type, the framework design, and the height of the framework.[120]

Only three studies[82,91,93] reported on the frequency of esthetic deficiencies, and the 15-year rate reached 9%. No specific esthetic outcome was measured in these studies, but it was stated that prostheses had to be replaced because of esthetic reasons. This finding may reflect the gradual degradation and discoloration of acrylic denture teeth in the oral environment.[121–123]

One important issue that should be mentioned is the validity of combining the results of studies performed at different time periods. If one study begins many years prior to a second study, it is distinctly possible that the results of the two studies may differ simply because of changes in the standards of practice that occurred during the time period covered by the two studies.[124] This "learning curve" has also been described in a retrospective study of treatment costs associated with implant-supported mandibular prostheses in edentulous patients.[125] The publication dates of the studies selected for the present review ranged from 1990 to 2008, with half of the studies published in the last 10 years. Despite the different time periods of the studies, higher complication rates were not seen for earlier studies. In fact, some of the later studies[90,95,97] presented with higher complication rates, eg, veneer fracture, compared to earlier studies. This could be explained by the fact that few changes in the materials and fabrication techniques of metal–acrylic resin IFDPs have been made over time.

The majority of prostheses in this study were mandibular metal–acrylic resin IFDPs. Maxillary IFDPs may present with different biomechanical challenges compared to mandibular IFDPs, given that they are more often opposed by natural teeth or implants and therefore are subjected to higher loading forces. The study design and result reporting of the included studies did not permit a direct comparison of complication rates between maxillary and mandibular prostheses.

Maintenance for IFDPs can be time consuming and costly. The prospective implant patient should be informed not only about the expected outcome of the treatment but also about its limitations. For the informed consent to treatment to be valid, the patient must be made aware of the risks of the treatment, the complications that may arise, and the additional costs involved in correcting them.[125]

The literature suggests that, in the hands of experienced operators,[6,23,92,100] complications occur frequently enough to concern clinicians of lesser experience. The retrievability of IFDPs is therefore an important consideration in delivering high-quality, patient-based treatment outcomes.

CONCLUSION

Complete metal–acrylic resin implant fixed dental prostheses presented with varying frequencies of complications over a period of 15 years. The most frequent complications were veneer fracture and material wear. Substantial amounts of chair time should be expected by the clinician following fabrication of an implant-supported restoration. More long-term studies are needed, especially regarding metal-ceramic complete implant fixed dental prostheses.

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