Implant survival and prosthetic complications of mandibular metal-acrylic resin implant complete fixed dental prostheses

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Statement of purpose. This study examined and recorded the long-term implant survival and prosthetic complications of patients treated with mandibular metal-acrylic resin implant complete fixed dental prostheses delivered in a private practice setting over a 22-year period.

Material and methods. Records were examined for all patients in the authors' private prosthodontic practices who between April 1988 and April 2011 had received mandibular metal-acrylic resin implant complete fixed dental prostheses supported by 4 to 8 implants and who had completed at least 1 year of follow-up after implant placement.

Results. Forty-five patients who had received a total of 247 implants met the inclusion criteria. In the course of the 1- to 22-year follow-up period (mean 8 years and 3 months), only 2 implants failed (0.81%) in 1 patient before definitive prosthetic reconstruction, which resulted in a cumulative implant survival rate of 97.78% ±2.2%. No screws were found to be loose or fractured. Individual denture-tooth fracture and chairside repair occurred 10 times in 5 patients. Because of wear, all the teeth had to be replaced by the laboratory 10 times in 8 patients between 5 and 12 years. Framework fractures occurred 6 times and affected 3 prostheses (twice for each of the 3 patients).

Conclusions. Implant failure was rare with this traditional mode of treatment and occurred before definitive restoration. The replacement of denture teeth due to wear or fracture was the most common prosthetic complication, and cantilevered frameworks exhibited a high risk of fracture when opposed by fixed prostheses. No fractures occurred for any of the frameworks opposed by complete dentures or removable implant prostheses. (J Prosthet Dent 2014;111:466-475)

Clinical Implications

Implants that support mandibular metal-resin implant complete dental prostheses demonstrate high implant survival rates that are not affected by prosthetic situations that require remediation over time. Clinicians should incorporate design parameters that address the potential of increased prosthetic complications when metal-resin implant complete dental prostheses are opposed by teeth or fixed prostheses in the maxillary arch.

Nearly 30 years ago, Brånemark[1] introduced the mandibular screw-retained metal-acrylic resin implant complete fixed dental prosthesis (MRICFDP), originally referred to as a hybrid prosthesis or fixed bone-anchored prosthesis,[2] to address the problems caused by unstable and uncomfortable mandibular dentures.[3,4] Initial data from Brånemark's Swedish study population indicated exceptionally high success rates for mandibular MRICFDPs and the implants that support them (100% and 97%, respectively, after 15 years).[5] This ground-breaking research provided support for a new era of implant treatment options for patients who were edentulous and partially edentulous. Continued university-based studies in Sweden, Belgium, and North America reproduced the success rates of Brånemark[1] for implants and fixed prostheses in edentulous mandibles.[6-8] As noted by Kopp[9] more than 2 decades ago, "the data demonstrate that the mandibular hybrid fixed prosthesis carries a low surgical risk and high restorative predictability." After documented successes for conventional implant protocols,[10] early

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and immediate loading protocols aimed at reducing treatment time also demonstrated predictable success in patients with edentulous mandibles.[10-14] Several researchers have reported high success rates by using immediate loading with mandibular fixed prostheses in private practice, but these studies are relatively short term (between 1 and 10 years).[15-19]

Although success rates of both the implants and prostheses are high for MRICFDPs, prosthetic complications can be problematic. Lindquist et al[20] found that lost fillings in screw-access openings and mobile prostheses were the most common complications associated with mandibular MRICFDPs, yet these were easy to manage, and, in the Toronto Study, Zarb and Schmitt[21] reported that fractured screws were easily replaced.

In their 15-year follow-up of 76 patients, Jemt and Johansson[22] found that, although implant and prosthesis survival rates remained high, the wear and fracture of denture teeth has been a significant problem. A recent meta-analysis conducted by Bozini et al[23] revealed a 66.6% incidence of acrylic resin fracture after 15 years of follow-up. In a Medline review, Goodacre et al[24] reported an incidence of resin-veneer fracture of implant fixed dental prostheses of 22%, much lower than the number reported by Jemt and Johansson,[22] but still concluded that it was a significant complication. Pjetursson et al[25] noted that these maintenance issues could be problematic in a busy restorative or prosthodontic practice.

Fracture of prosthesis frameworks is the most serious and costly prosthetic complication. An incidence of 8.8% after 15 years was reported by Bozini et al.[23] Makkonen et al[26] and Johannsson and Palmqvist[27] also observed that the fracture of superstructures was a significant problem related to mandibular MRICFDPs. In a 5-year follow-up of 37 patients, Davis et al[28] observed that the incidence of framework fracture was much higher when both arches received fixed implant restorations and the fractures occurred at the beginning of the cantilever arms. Attard and Zarb[29] reported similar results: 10 of 33 frameworks fractured after 8 to 23 years, and the fractures occurred at the cantilevers in all but 1 patient. Other researchers, however, have not detected framework fractures even for prostheses opposing natural dentitions.[15,30-32] In those studies that reported framework fractures, potential causes have been correlated with increased occlusal forces with fixed implant restorations,[33] flaws of casting technology,[34] and cantilever length.[35] The present retrospective patient investigation examined the survival rate of implants that support MRICFDPs that were provided in a private practice setting with both delayed and immediate protocols, and were followed-up for up to 22 years. Based on the authors' data and experiences, prosthetic complications and methods for improving prosthesis design and predictability also were examined.

MATERIAL AND METHODS

Two prosthodontists in private practice examined patient records contained in a database maintained by the practice. It was updated weekly and documented patient progress as noted during routine recall visits, emergency examinations, and revision appointments. Inclusion criteria for patients in this retrospective examination were that they were at least 16 years old; had one of the following diagnoses, unstable or uncomfortable mandibular dentures, congenitally missing teeth, or failing remaining teeth, with a preference for a fixed dental prosthesis or an intolerance to removable prostheses; were restored with implants and mandibular screw-retained MRICFDPs between April 1988 and April 2011; and had completed at least 1 year of follow-up after implant placement.

Forty-five patients who were treated with a total of 247 implants to restore their edentulous mandibles met the inclusion criteria. A total of 10 oral surgeons and 3 periodontists placed the implants; the present authors delivered prosthetic care, and 2 dental laboratories fabricated the prostheses. Patients ranged in age from 16 years (a patient with ectodermal dysplasia) to 86 years; the mean age was 61 years. Thirty-one patients were women, and 14 were men. Follow-up time from the time of implant placement ranged from 1 to 22 years, with a mean observation time of 8 years and 3 months. Follow-up from the time of definitive prosthesis placement ranged from 8 months to 20 years 6 months, with a mean of 7 years and 2 months. Although 8 patients received immediate provisional fixed dental prostheses, follow-up time was calculated by using the seating date of the definitive prostheses for all the patients.

Patients who met the inclusion criteria were reexamined for this study. Those who had moved from the area or were unable to continue maintenance appointments were contacted by telephone to obtain detailed information about their implants and prostheses. If other dentists had treated the patients after geographic relocation, then those dentists were contacted, and records were reviewed when appropriate. Patients who were deceased but had completed at least 1 year of follow-up also were included. This type of analysis enabled a realistic appraisal of the successes, failures, and maintenance issues that are faced in a typical prosthodontic private practice setting. The focus of the patient examination was implant survival as well as mandibular prostheses longevity and prosthesis complications that required remediation. The types of restorations in the opposing maxillary arches were recorded, but their continued status was not included in these data.

Statistical methods

Although a patient could have multiple implants, the individual patient was the unit of analysis. Failures and qualitative variables were expressed as percentages. Failure time was defined as the time to first implant failure for any given patient and was

TABLE I. Participant data

Participants			Implants					Significant Complications				
No.	Sex	Age (y)	No.	Immediate Delayed	Implants Duration (mo)	Prosthesis Duration (mo)	Opposing Arch	Implant Failure	Framework Fracture	Incidence of Single Tooth Fractured Chairside Repair	All Teeth Worn and/or Fractured Replaced in Lab	Prosthesis Replaced
1	F	43	5	Delayed	254	246	Denture				1	
2	F	55	6	Delayed	252	228	Fixed imp			2	2	
3	M	52	5	Delayed	250	244	Denture					
4	F	50	6	Delayed	209	202	Fixed imp			2	2	
5	F	40	5	Delayed	194	183	Imp over				1	
6	F	86	5	Delayed	66	59	Denture					
7	F	55	4	Immediate	127	28	Denture					
8	F	53	5	Delayed	205	194	Denture				1	
9	F	63	5	Delayed	168	158	Fixed imp					
10	M	63	8	Delayed	169	161	Denture	2				
11	M	63	5	Delayed	171	163	Denture					1
12	F	56	6	Delayed	21	15	Fixed imp					
13	M	65	5	Delayed	149	28	Denture					1
14	M	67	7	Delayed	122	116	Denture					
15	F	70	8	Delayed	139	133	Teeth					1
16	F	60	5	Delayed	129	125	Fix teeth/imp		2		1	1
17	F	57	5	Delayed	126	121	Fixed imp		2	2	1	2
18	M	16	5	Delayed	123	115	Imp over					
19	F	77	5	Delayed	113	106	Denture					
20	M	63	5	Delayed	104	94	Imp over					
21	M	58	8	Delayed	98	92	Fixed imp			3		1
22	M	73	5	Delayed	84	75	Denture					
23	F	72	6	Immediate	84	76	Teeth FDP					
24	F	55	5	Immediate	86	81	Teeth					
25	M	56	5	Immediate	85	73	Denture					
26	M	56	7	Delayed	73	68	Imp over					
27	F	54	5	Delayed	73	64	Teeth RDP					
28	F	60	4	Delayed	79	70	Denture				1	
29	M	74	4	Delayed	71	65	Teeth					
30	M	57	5	Immediate	69	51	Teeth					
31	F	79	5	Delayed	59	53	Teeth		2			2
32	F	38	5	Delayed	56	46	Teeth					
33	F	60	5	Delayed	56	48	Denture					
34	F	68	5	Delayed	65	60	Imp over					
35	F	66	5	Immediate	65	56	Denture					
36	F	83	5	Delayed	31	23	Denture					
37	F	65	6	Delayed	32	24	Denture					

(*Continued*)

TABLE I. (*Continued*) Participant data

Participants			Implants					Significant Complications				
No.	Sex	Age (y)	No.	Immediate Delayed	Implants Duration (mo)	Prosthesis Duration (mo)	Opposing Arch	Implant Failure	Framework Fracture	Incidence of Single Tooth Fractured Chairside Repair	All Teeth Worn and/or Fractured Replaced in Lab	Prosthesis Replaced
38	F	59	4	Delayed	46	36	Denture					
39	F	77	5	Delayed	34	27	Teeth					
40	M	61	5	Immediate	33	27	Fixed imp			1		
41	F	61	6	Delayed	28	17	Denture					
42	F	52	6	Delayed	22	14	Fixed imp					
43	F	68	5	Delayed	16	9	Denture					
44	F	61	6	Immediate	20	15	Imp over					
45	F	74	5	Delayed	14	8	Teeth					
	31F	61	245	38 Delayed	Mean	Mean	Dent/over 26	2	6	10	10	9
	14M		2 failed	8 immediate	99.3	86.6	Fixed teeth/imp 19		4 cast 2 CAM			

Fixed imp, fixed implant prosthesis; Imp over, implant overdenture; RDP, removable dental prosthesis; FDP, fixed dental prosthesis.

estimated by using the nonparametric Kaplan-Meier method.[36] Because the error rate for all inferential statistics was set at .05, the level of the confidence intervals was 95%. All computations were completed with software (SAS/Base and SAS/Stat 9.1; SAS Institute).

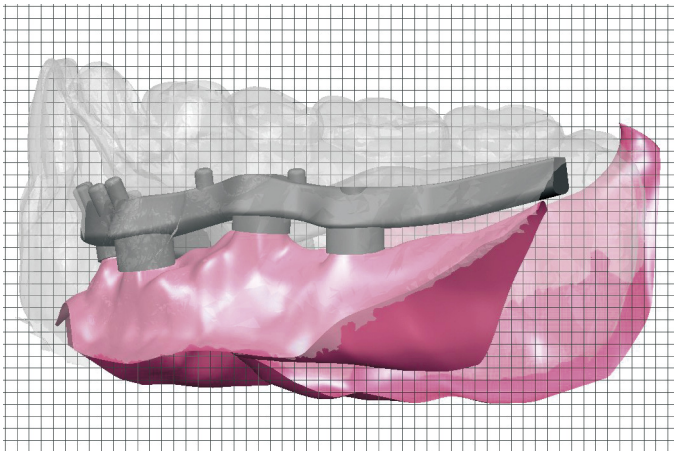
RESULTS

Patient data, including the number of implants and significant complications, are listed in Table I. Two-hundred forty implants were placed in the interforaminal region of the 45 patients, with 28 patients classically restored with 5 interforaminal implants, 4 patients with 4 implants, 9 patients with 6 implants, 2 patients with 7 implants, and 2 patients with 8 implants. Only 7 implants were placed distal to the mental foramina., The current status of all but 1 of the patients was obtained. Thirty-five of the 45 were still active in the practice, 7 were interviewed by telephone, and 2 were deceased.

All the patients received antibiotic prophylaxis before surgery. Three patients underwent grafting with autogenous bone from the iliac crest before implant placement, and 5 implants were placed in each of these mandibles after complete healing. Two hundred twenty-two implants were manufactured by Biomet 3i, 15 by Nobel Biocare, 6 by Biohorizons, and 4 by Zimmer Dental. Nineteen prostheses opposed either natural teeth or fixed dental prostheses supported by teeth or implants, 21 opposed complete dentures, and 5 opposed removable implant-retained prostheses.

In the earlier years, patients (n=28) were treated with a 2-stage surgical protocol. For these patients, a surgical guide was made by the prosthodontists and delivered to the implant surgeon. Implants were placed and uncovered 3 to 6 months later. An existing or provisional denture that was soft lined was placed after initial surgery and again relined after implant uncovering and placement of healing abutments. In later years (n=9), implants were placed in a single-stage surgery and temporarily restored with soft-lined dentures. The most recently delivered implants were placed immediately after tooth extraction and were immediately restored with fixed provisional restorations that were converted chairside by the prosthodontists from existing or newly fabricated dentures (n=8). This conversion was accomplished by attaching temporary cylinders to the implants and affixing the cylinders to the prostheses intraorally with autopolymerizing resin. The gingival surfaces of the prostheses were contoured and polished, and designed to be free of soft-tissue contact. All interim prostheses were screw retained and tightened to the force recommended by the implant manufacturers. Access openings were filled first with a cotton pellet placed over the abutment screw, followed by a layer of fast-setting polyvinyl siloxane. Patients were advised to consume a soft diet for 8 weeks.

All but 4 patients received their definitive implant prostheses within 1 year of implant placement. Impressions were made by using an open-tray technique. Pick-up impression copings were splinted with dental floss and autopolymerizing acrylic resin (GC



1 Earlier use of hand waxing was replaced by virtual framework design in later prostheses.

2 Digital design files interfaced with computer-controlled milling machines to produce precisely machined titanium frameworks.

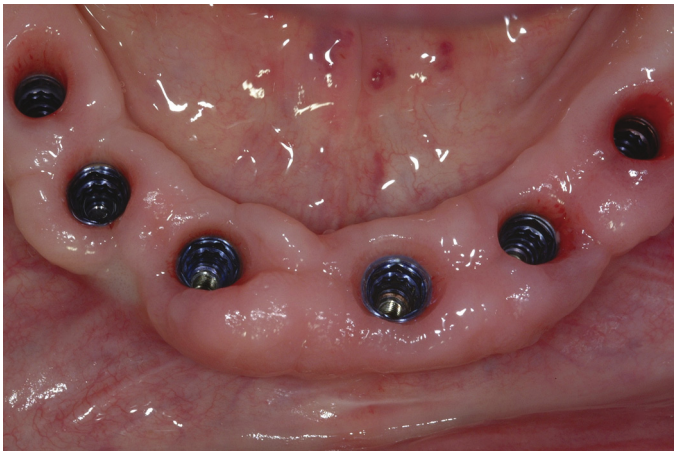
3 Completed titanium frameworks were processed with nanocomposite resin teeth and characterized gingival acrylic resin.

resin; GC America). Openings or windows were made over the impression-coping access openings in the stock trays, and definitive impressions were made with polyvinyl siloxane. Cast accuracy was then ascertained by using cast-verification indices that were made with temporary implant cylinders luted together on the casts with the same autopolymerizing resin. The indices were evaluated intraorally, and impressions were remade if a discrepancy was detected. No frameworks had to be sectioned and reassembled because of misfits.

Jaw-relation records were completed with a facebow, occlusion rims, centric relation record, and semi-adjustable articulator. Early frameworks were waxed and then cast in noble alloy (n=17), whereas all later versions (n=28) were virtually designed and fabricated in titanium alloy (Figs. 1, 2) with a computer-assisted design/computer-assisted manufacturing system (Architecture CAM StructSURE; Biomet 3i). Acrylic resin or nanocomposite resin denture teeth were used for all prostheses and processed with characterized pink acrylic resin (Fig. 3). Prostheses extended to 1 premolar and 1 molar for 2 patients, 2 premolars and 2 molars for 3 patients, and 2 premolars and 1 molar for all remaining patients. A group function occlusal scheme was used, which avoided excursive contacts on cantilevered teeth (Fig. 4). Definitive prostheses were seated and tightened to the torque recommended by the implant manufacturers (Figs. 5, 6). Earlier access openings were filled first with a cotton pellet over the screw, followed by a layer of gutta percha dental stopping and finished with 2 mm of either acrylic resin or composite resin (Fig. 7). In later prostheses, Teflon plumbers tape E. I. du Pont de Nemours and Company was used in lieu of cotton pellets and dental stopping. Postseating radiographs were made to assess implant integration and prosthesis fit (Fig. 8). Patients were examined on regular recall visits, usually biannually, or as was required during revision appointments.

This series of dental patients (n=45) with implants placed between 1988 and 2011 was followed-up for up to 22 years. All the patients had 4 to 8 implants each and a total of 247 implants were placed. The mean evaluation period was 8 years and 3 months, with a minimum follow-up of 1 year

4 Distal cantilevers typically extended to mandibular first molar and group function occlusion established.



5 Upon removal of easily cleansable interim fixed dental prosthesis, soft tissue was observed to be relatively free from inflammation.

6 Seated prostheses functionally and esthetically integrated with opposing complete denture.

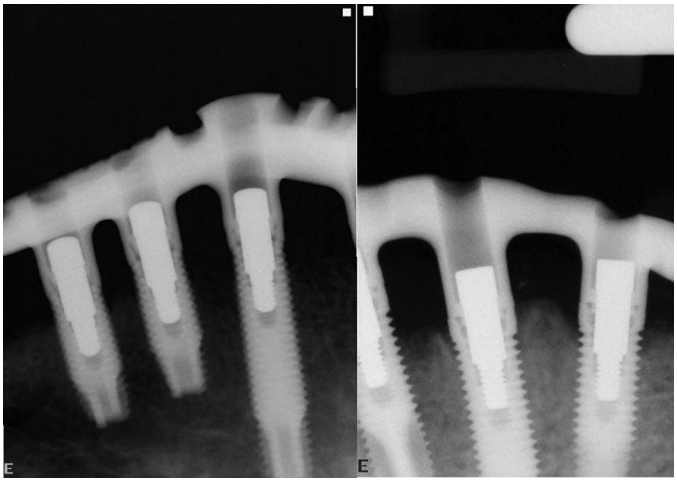
and a maximum follow-up of 22 years. During that period, 2 implants failed in 1 patient at 1.9 months, before prosthetic rehabilitation. By using the lower limit of the Kaplan-Meier 95% confidence interval,[36] the cumulative implant survival rate was 97.78% ±2.2% for these patients. Also when using the lower limit of the Kaplan-Meier 95% confidence interval, these implants were deemed successful for 266.8 months in more than 93.5% of patients.

Minimal bone loss was observed radiographically in all the patients. Sore spots that developed during interim denture wear occasionally required relief. Otherwise, no significant surgical complications were documented. Most notably, no implants failed in any patient after prosthetic rehabilitation during the retrospective study period, and all patients remained in continuous function with fixed prostheses.

The definitive prostheses were observed for a mean of 7 years and 2 months, with a minimum follow-up of 8 months and maximum follow-up of 21 years. Prosthetic complications occurred more frequently than implant failures. Occlusal access filling material dislodged in a few early patients (Fig. 9), but this was rectified by placing undercuts in the openings with an inverted cone bur to mechanically lock the acrylic resin or composite resin in place. The most common prosthetic complication was the replacement of all acrylic resin teeth because of wear or fracture. This occurred 10 times, which affected 8 patients whose prostheses were in service from 5 to 10 years (mean, 7 years) and 2 patients whose teeth were replaced twice (at 5 and 7 years and at 5 and 12 years, respectively). More rapid denture-tooth wear and fractured denture teeth were noted in prostheses that opposed natural teeth or fixed dental prostheses. Prosthetic tooth replacement unrelated to wear or fracture of denture teeth was required in another 10 instances due to framework fracture (6) or compromised framework design (4). Fracture of individual denture teeth or the acrylic resin that surrounded the frameworks that was repaired chairside occurred 10 times in 5 patients. One prosthesis was removed, and acrylic resin was added to the gingival aspect because the patient stated that the space was too large and was trapping food.

Framework fracture occurred 6 times and involved 3 patients (twice for each patient) and occurred early in all treatments, between 1 and 3 years. Two

7 Occlusal screw access openings filled with cotton pellets, gutta percha dental stopping, and acrylic resin or composite resin.



8 Postseating radiographs demonstrated nearly seamless interface between framework and supporting implants.

9 Early prosthesis opposing maxillary fixed dental prosthesis demonstrated tooth wear and dislodgement of occlusal access material after 8 years in service.

of the 3 patients reported a positive history of parafunctional habits. Of the 6 frameworks that fractured, 4 were cast noble alloy, and 2 were computer-assisted design/computer-assisted manufacturing milled titanium alloy. Five of the 6 were completely remade, and 1 was laser welded and repaired, and then new teeth were processed. All fractures occurred distal to the most distal implant and only in prostheses that were opposed by either natural teeth or a fixed prosthesis supported by teeth or implants.

Four additional frameworks were remade because of the inadequate retention of denture teeth. Nine prostheses, therefore, were completely remade because of framework fractures or inadequate framework design. No loose or broken retaining or abutment screws were reported. The only significant soft-tissue complication related to prosthesis design was hyperostosis beneath the distal cantilevers of 1 patient.

DISCUSSION

Results for this private practice population treated over a 22-year period with mandibular MRICFDPs included favorable rates of implant survival and prosthesis stability, comparable with or higher than reported in long-term university settings.[6-8,37,38] These outcomes presented further substantiate the existing shorter-term data on immediate restorations.[10,11,15-17,26,30,39] In this population, the few implant failures that were noted occurred before prosthetic rehabilitation; after restoration, implants survived for up to 22 years. All the patients remained in continuous function with their fixed prostheses throughout the examination period, although 9 prostheses had to be completely remade (5 because of framework fracture and 4 because of framework design flaws), unrelated to implant failure. The authors' experience presented is similar to studies reviewed in the meta-analysis by Bozini et al[23]; prosthodontic complications did not adversely affect implant survival. Other researchers have recognized the same trends: few implant failures occurred in edentulous mandibles, with most of those documented before restoration.[29,40-42] Positive outcomes reported by other researchers for immediate implant placement and provisional

restorations[10,13,14] led the authors to adopt these protocols in more recent years. The only significant soft-tissue complication related to prosthesis design was hyperostosis beneath the distal cantilevers of 1 patient, a complication also reported by Taylor.[43] This framework was removed, relieved over the area of hyperostosis, and reseated, and the patient remained comfortable throughout the observation period.

Although the Toronto study reported fractured screws, which were easily replaced,[21] no screw fractures were encountered in the present study population. In the authors' experience, screw loosening almost never occurred after the introduction of implants with internal abutment connections and consistent use of torque devices. Although filling material dislodged in earlier patients, this became rare once mechanical undercuts were placed in access openings.

Wear and/or fracture of individual resin denture teeth that were repaired chairside occurred 10 times in 5 patients (incidence of 11%). As also reported by Purcell et al,[40] anterior tooth fracture was more common than posterior tooth fracture. Generalized wear resulted in complete replacement of the acrylic base and teeth in 10 prostheses and 8 patients (incidence of 18%). Therefore, total complications that related to tooth replacement due to wear and fracture occurred 20 times in 13 patients (incidence of 29%). Tooth replacement due to framework refabrication, unrelated to tooth wear or fracture, occurred in another 9 prostheses. Notably, the most commonly encountered complication, tooth replacement, was not particularly problematic in this private practice setting. Individual tooth fracture was repaired chairside, and the authors considered replacement of worn teeth that occurred over a period of years to be a normal maintenance procedure that was accomplished with little difficulty. The patients were made aware of this contingency at the beginning of treatment and were very accepting of these revisions and the costs involved. These results are in contrast to the high incidence of tooth fracture presented by other researchers.[22,23] The disparity in these results may be the result of differing reporting methods. The present authors listed wear as a complication only when tooth replacement was necessary. All denture teeth, however, demonstrated some degree of wear over a period of years, particularly when opposed by fixed prostheses in the maxillary arch.

Framework fracture occurred in 6 prostheses in 3 patients, an incidence of 13.3% per prosthesis and 6.7% per patient. In this study population, fractures occurred only when the prostheses were opposed by natural teeth or fixed prostheses supported by teeth or implants and usually in patients with parafunctional habits. This incidence is higher than that found in the meta-analysis by Bozini et al.[23] Complete dentures, however, opposed most of the prostheses reviewed in that analysis. Davis et al[28] and Attard and Zarb,[29] also discovered that the rate of framework fracture was higher when both arches received fixed implant restorations and the fractures occurred at the beginning of the cantilever arms.

Framework fracture in this population that occurred only when MRICFDPs were opposed by fixed restorations may also be related to increased occlusal forces. Mericske-Stern and Zarb[44] indicated that implants supporting fixed prostheses were not likely to increase maximum occlusal forces in the presence of maxillary complete dentures. Jemt et al[33] demonstrated that occlusal forces increased significantly over time when patients were switched from a mandibular removable bar overdenture to a fixed prosthesis. Jacobs et al[45] demonstrated a significant downward shift of power frequency during sustained clenching after rehabilitation with implant-supported overdentures but not with implant-supported fixed prostheses. Falk et al[46] demonstrated that 70% of the occlusal forces were borne by the cantilever sections and concluded that the framework was most vulnerable distal to the distal implant and should have adequate height to withstand the forces on the cantilever section.

Another cause of framework fracture may be related to the imperfections of casting technology. Four of 17 cast noble alloy frameworks (23.5%) and only 2 of 28 computer-assisted design/computer-assisted manufacturing titanium frameworks (7.1%) fractured in this patient population. Although the titanium frameworks were in service for a shorter period, the cast frameworks fractured early, between 1 and 3 years. Carr and Stewart[34] observed that conventional lost-wax casting techniques for complete-arch implant frameworks are both imprecise and inaccurate as judged against the passive fit requirement. Computer-milled titanium frameworks made of homogeneous blocks of titanium have greater strength than potentially porous cast alloys and demonstrate improved precision of fit.[47,48]

Potential framework fracture also has been correlated with cantilever length, although no specific correlation was found in the present population. In a 15-year follow-up, Lindquist et al[20] concluded that cantilever lengths were of minor importance. Sertgoz and Guvener[35] suggested a mandibular extension of between 15 and 20 mm to minimize risk. English[49] and Takayama[50] recommended a cantilever length 1.5 times or 2 times, respectively, the anterior posterior curve of the implants. McAlarney and Stavropoulos,[51] however, indicated that the determination of cantilever length should not be based solely on the anterior posterior spread of the implants but should also consider the opposing occlusion and the number and distribution of implants.

In the present study, the incidence of framework fracture in those resin-metal fixed prostheses opposed by fixed restorations was 25% (3 of 12 patients), an unacceptable risk in the authors' opinion. The present results are similar to those of Davis et al,[28]

who found that cantilevered mandibular fixed prostheses opposed by natural teeth or fixed implant prostheses had a higher incidence of complications.

The frequency of framework fractures in the cantilevered sections of mandibular prostheses opposed by fixed maxillary dental prostheses in this study warrants special consideration. An obvious solution is to avoid mandibular frameworks with posterior cantilevers against maxillary fixed prostheses, and to reserve the use of mandibular cantilevers only when opposed by maxillary dentures or removable implant prostheses. Implants could be placed distal to the mental foramina to eliminate or shorten cantilevers. Other practical suggestions include keeping the cantilever as short as possible to reduce framework stress, extending distally no further than the mandibular first molar for most patients. Tipping the most distal implants distally will reduce cantilever length without compromising implant success rates.[52] As recommended by Stewart et al,[53] increased vertical framework thickness in cantilevered sections improves fatigue strength. Zirconia frameworks may be a promising alternative to titanium alloys. In at least 1 short-term study of 10 patients, no frameworks fractured in a 3-year period.[54] If the vertical space for a substantial framework is inadequate, then an implant overdenture might provide an alternative restorative approach.

CONCLUSION

Extensive patient documentation by numerous researchers over the past 30 years has led to significant refinements in materials and techniques for mandibular MRICFDPs, a treatment method that has evolved into a contemporary option that effectively serves the needs of many patients who are edentulous. This retrospective evaluation of 45 patients treated with mandibular MRICFDPs and 247 implants and followed up in private practice over a 1- to 22-year period revealed that

1. Implant failure was rare, with a cumulative implant survival of 97.78% ±2.2%. All failures occurred before prosthetic reconstruction. Prosthetic complications did not impact implant survival rates.

2. Cumulative survival rates were equally high for immediately placed and provisionally restored implants and for those placed with conventional delayed protocols.

3. Prosthetic complications of screw loosening and fracture were rare.

4. Tooth wear and fracture were the most common prosthetic complications that required remediation.

5. Framework fracture, the most significant prosthetic complication, occurred at an overall rate of 13% and only when opposed by teeth or fixed dental prostheses supported by teeth or implants.

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