Long-term survival of endodontically treated molars without crown coverage: A retrospective cohort study

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Statement of problem. Teeth are weakened after endodontic treatment and should, ideally, be crowned, especially posterior teeth. However, this is not always possible. Information about the longevity of endodontically treated teeth without crown coverage may assist in selecting appropriate treatment modalities.

Purpose. The aims of this cohort study were to evaluate the survival rate for endodontically treated molars without crown coverage and to identify possible related factors.

Material and methods. A total of 220 endodontically treated permanent molar teeth in 203 subjects on a waiting list for fixed prosthodontic treatment at the Faculty of Dentistry-Mahidol University, Thailand, were included. Follow-up data were derived from a clinical examination and review of the dental record and radiographs. Subjects were not included in the study if teeth had provisional crowns, definitive restorations with cuspal coverage, or with dowel and core and/or crown restorations. The outcome evaluated was defined as a failure if there were negative findings in the condition of a tooth that required a restoration, tooth repair, or extraction. Tooth loss due to endodontic and periodontal reasons was excluded. The independent variables assessed were patient age, gender, location (maxilla or mandible), the existence of an opposing dentition and adjacent teeth, remaining tooth structure, and types of restorative material. Kaplan-Meier analysis with a 95% confidence level was used to calculate the survival probability, and a log-rank test was used to determine whether significant differences existed.

Results. Overall survival rates of endodontically treated molars without crowns at 1, 2, and 5 years were 96%, 88%, and 36%, respectively. With greater amounts of coronal tooth structure remaining, the survival probability increased. Molar teeth with maximum tooth structure remaining after endodontic treatment had a survival rate of 78% at 5 years. Restorations with direct composite had a better survival rate than conventional amalgam and reinforced zinc oxide and eugenol with polymethacrylate restorations.

Conclusion. Within the limitations of this study, the amount of remaining tooth structure and types of restorative material have significant association with the longevity of endodontically treated molars without crown coverage. (J Prosthet Dent 2005;93:164-70.)

CLINICAL IMPLICATIONS

The results of this study support the necessity of crown placement in endodontically treated molars. However, in conditions where endodontically treated molars are otherwise completely intact, except for a conservative access opening, the molars may be restored successfully for extended periods of time using resin composite restorations.

An occlusal coverage restoration is considered an optimum treatment[1-3] and should provide improved longevity of endodontically treated teeth.[4] Various reasons for tooth loss after endodontic treatment have been reported by Caplan and Weintraub.[5] However, there are 2 primary factors related to the recommendation for crown placement. These factors are the loss of tooth vitality and the loss of tooth structure after endodontic treatment.[6]

Previously, it was believed that biological changes occurred in teeth after endodontic treatment, rendering them more brittle and susceptible to failure.[7] In a matched-pair study of vital and endodontically treated human teeth, Papa et al,[8] however, reported no significant differences in moisture content. The biomechanical properties, punch shear strength, toughness, hardness, and load to fracture of endodontically treated teeth were also evaluated in another matched-pair study by Sedgley and Messer,[9] which concluded that teeth do not become more brittle following endodontic treatment.

Endodontically treated teeth often lose substantial tooth structure from previous caries, pre-existing restorations, and/or endodontic procedures. Reduction in tooth bulk and loss of sound dentin resulting from

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tooth preparation causes weakening of teeth.[6,10-12] Controversy exists as to whether endodontic procedures are the primary cause for the loss of strength for a tooth. Panitvisai and Messer[13] reported that cuspal deflection increased with the extension of cavity preparations and was greatest when endodontic access was incorporated into a preparation. However, Reeh et al[14] performed a similar nondestructive test of cuspal stiffness that allowed sequential testing on the same tooth. Tooth modification involving endodontic access was evaluated both before and after cavity preparation. It was concluded that endodontic procedures had only a small effect on tooth strength. Rather, it was the advancing preparation that caused reduction in the relative stiffness of the tooth. Steele et al[15] confirmed this finding. Similar fracture resistance was found in endodontically treated teeth with canal access only, as compared to unaltered natural teeth. The significantly lowest compressive strength was found in teeth with mesiocclusodistal (MOD) preparations. In addition, restoration of the MOD preparation improved the strength of the tooth, but these teeth still had a significantly lower fracture resistance than intact teeth.[15,16]

Although, crown restoration has been advocated as a means to strengthen a tooth after endodontic treatment, tooth fractures are common even after crown placement.[17-19] In a study on the incidence of tooth mortality in a Swedish population, Eckerbom et al[17] found that endodontically treated teeth with crowns were lost at the same rate as vital teeth. Gher et al[18] in a clinical survey of 100 fractured teeth, indicated that even though the endodontically treated teeth with complete crowns seemed to have a better prognosis than teeth without crown treatment, crown coverage did not prevent root fracture. Dowel placement used to retain a core restoration was often found to be the primary cause of root fracture[20,21] and the preparation of a dowel space markedly weakened an endodontically treated tooth.[22] Therefore, if there is adequate remaining coronal tooth structure to retain a restoration, direct treatment can be provided without a dowel.[23]

Documentation regarding the use of various direct restorative materials and techniques in compromised teeth have shown good prognosis in vitro.[24-32] Wilson et al[33] in a clinical evaluation of the performance of posterior composite restorations, reported a low failure rate (14%) in large and moderately sized restorations of vital teeth over 5 years of service. The satisfactory use of adhesive restorative systems for endodontically treated teeth[24-26] and cracked teeth[27] also has been suggested. Reeh et al[28] investigated the potential for alternative restorative techniques with nonvital teeth. Standardized MOD preparations were used. The results showed that composite restorations with enamel-dentin etching had a relative stiffness close to that of the unaltered tooth. Amalgam restoration provided little or no resistance to cuspal movement, while a gold onlay provided greater resistance to movement than that of the unaltered tooth. Loading the teeth to fracture produced different results. The strength of teeth restored with amalgam or composite was significantly lower than teeth restored with gold onlays and unaltered teeth. The authors noted that the load used in the destructive testing was high relative to clinical conditions, unlike in nondestructive testing, where a load was selected at the upper limits of physiologic occlusal force, resulting in the conclusion that teeth might fracture at maximum possible forces, but not at clinically relevant loads.

Unfortunately, there is only limited information available regarding the clinical performance and survival of endodontically treated teeth without crown coverage. In a 20-year retrospective study, Hansen et al[34,35] reported that survival rates of MO/DO preparations were significantly higher than MOD preparations in endodontically treated teeth restored with amalgam. However, no significant difference was found when teeth were restored with composite material. The only prospective study identified that compared performance between the uncrowned and crowned endodontically treated teeth was conducted by Mannocci et al.[36] Endodontically treated premolars with 2-surface interproximal carious lesions and preserved cusp structure were restored with a fiber dowel (Composipost; RTD, St. Egreve, France) and a direct composite restoration (Z100; 3M ESPE, St. Paul, Minn) with and without complete crown coverage. Clinical performance was evaluated after 3 years of service, and the results showed similar success rates. There was no report of fracture or tooth loss. The aims of this study were to evaluate the survival rate of endodontically treated molars without crown coverage and to identify possible explanations for the differences observed.

MATERIAL AND METHODS

Subjects were patients of record from the Department of Prosthodontics clinic, Mahidol University, Thailand, and had been on a waiting list for post-endodontic-therapy, fixed prosthodontic treatment since 1991. Endodontic therapy was performed by dental students under instructor supervision. The root canals were prepared using a step-back technique and obturated with gutta percha using lateral condensation. After completion of the endodontic therapy, teeth were provisionally restored with various direct restorations. Patients were then placed on a waiting list for a crown. However, only a minority of teeth were crowned within a year due to economic reasons and university educational requirements. In addition, direct composite restorations were provided for patients who were undecided about crowns or unable to obtain crowns within 1 year.

Table I. Descriptive data and logrank analysis

Variable	Number of teeth	Number failed	*P* value
Gender			0.1508
Male	59	27	
Female	161	74	
Age interval (years)			0.8385
<20	38	15	
20-60	163	77	
<60	19	9	
Location			0.1375
Maxilla	81	34	
Mandible	139	67	
Opposing dentition			0.2529
Natural, FPD	197	93	
None, RPD	22	7	
Proximal contact			0.2467
2	83	41	
0 or 1	137	60	
Remaining tooth structure			0.0003
Type I	27	4	
Type II	120	47	
Type III	73	50	
Types of restoration			0.0083
Composite	195	82	
Amalgam	14	10	
IRM	11	9	

FPD, Fixed partial denture; *RPD*, removable partial denture.

After the protocol was approved by the Committee on Human Rights Related to Human Experimentation, Mahidol University, clinical evaluation of endodontically treated molars was initiated from April 2002 to November 2002. To identify suitable subjects for participation in this study, all patients with endodontically treated molars were identified and recalled for clinical examination. The status of the patients was updated in terms of patient intent to continue with the treatment at the dental school and to observe the present condition of a tooth or teeth in question. Potential carious lesions, questionable crown or root fractures, loss of restoration, and tooth loss were recorded. In addition, dental records were reviewed for baseline data on the date of endodontic completion, previous changes in tooth condition, and, also, to identify data regarding emergency treatment, if available, for these teeth. Routinely, patients were on a 6-month, and 1-, 2-, and 5-year post-endodontic recall program. However, not all continued to attend. Patients were also asked about any changes in tooth condition. Only permanent molars that had not received provisional crowns, definitive restorations with cuspal coverage, dowel and core restorations, and/or crowns at the time of recall were included. Third molars and teeth with less than half of occlusogingival tooth height remaining at the time of endodontic treatment were excluded. Radiographs were also reviewed to verify the data.

Treatment outcome was defined as a failure if there were negative findings in the condition of a tooth that required a restoration, tooth repair, or extraction. Failure characteristics of tooth changes included recurrent caries at the margin of a restoration, crack/fracture line, loss of restoration, fracture of tooth or restoration, and/or vertical root fracture. A change in color was not considered failure. Endodontically treated teeth that were lost because of endodontic and periodontal reasons were also excluded.

The following independent variables were assessed: patient age, gender, location (maxilla versus mandible), the existence of opposing dentition (natural teeth, fixed partial denture versus none, removable partial denture) and adjacent teeth (none, 1 versus 2 proximal contacts), remaining tooth structure, and types of restorative materials. To judge the amount of remaining tooth structure, a criterion-based evaluation was developed by the authors, defining 3 types of remaining tooth structure. Type I remaining tooth structure denoted maximum remaining tooth structure. The amount of remaining coronal tooth structure was approximately that of a Class I cavity preparation with at least 2 mm of surrounding wall thickness. Type II denoted moderate remaining tooth structure. The amount of remaining coronal tooth structure was approximately a Class II cavity preparation with no less than 2 walls with at least 2 mm thickness. Type III denoted minimum remaining tooth structure as the remaining coronal tooth structure had less than 2 walls with at least 2 mm thickness, and teeth could not be classified as Type I or II. The 220 endodontically treated molars in 203 subjects that satisfied the inclusion criteria were included in this study. The age range of the subjects was between 15.3 and 74.7 years; 161 of the subjects were women and 59 were men. The observation period ranged from 6 months to 10.2 years. The follow-up began from the date of endodontic therapy completion and ended on the date of negative findings in a tooth condition and/or tooth extraction. For teeth that were not determined a failure, follow-up ended on the date of data collection in the clinic.

A Kaplan-Meier analysis with a 95% confidence level was used to calculate the survival probability, and a log-rank test was used to determine whether significant differences existed for each independent variable and survival outcome. The relatively small sample size and inconsistent failure over time prevented the use of a Cox proportional hazards model in evaluating potential risk factors related to survival.[37]

RESULTS

Of the 220 teeth examined, tooth failure was identified in 101 teeth (45.9%). Of these failures, 14 teeth were determined unrestorable and were extracted,

Table II. Kaplan-Meier analysis of median survival time and survival estimates

	Median survival time in years (±SE)	Estimated survival probability (±SE)		
		1-year	2-year	5-year
Overall	3.7 (0.4)	0.96 (0.01)	0.88 (0.02)	0.36 (0.05)
Remaining tooth structure				
Type I	>7.9*	0.95 (0.04)	0.95 (0.04)	0.78 (0.12)
Type II	4.4 (0.8)	0.97 (0.02)	0.91 (0.03)	0.45 (0.06)
Type III	3 (0.1)	0.94 (0.03)	0.80 (0.05)	0.18 (0.06)
Type of restoration				
Composite	4.2 (0.3)	0.96 (0.01)	0.90 (0.02)	0.38 (0.05)
Amalgam	3 (0.6)	0.93 (0.07)	0.77 (0.12)	0.17 (0.14)
IRM	2.2 (0.3)	0.91 (0.09)	0.60 (0.15)	0.20 (0.13)

*Observation time limited to 7.9 years.

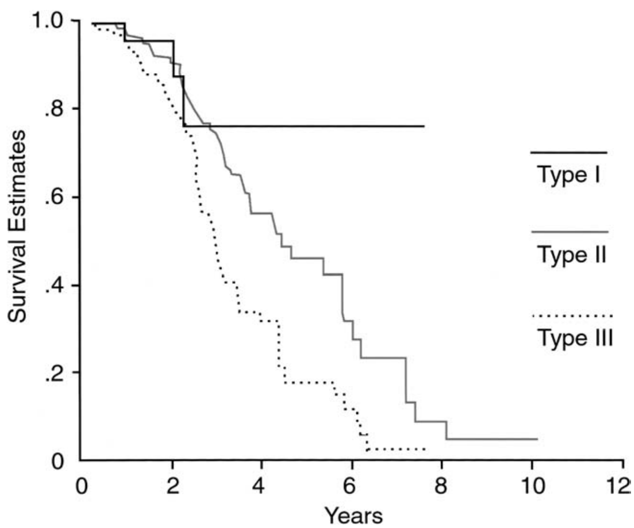

Fig. 1. Kaplan-Meier survival curves according to amount of remaining tooth structure.

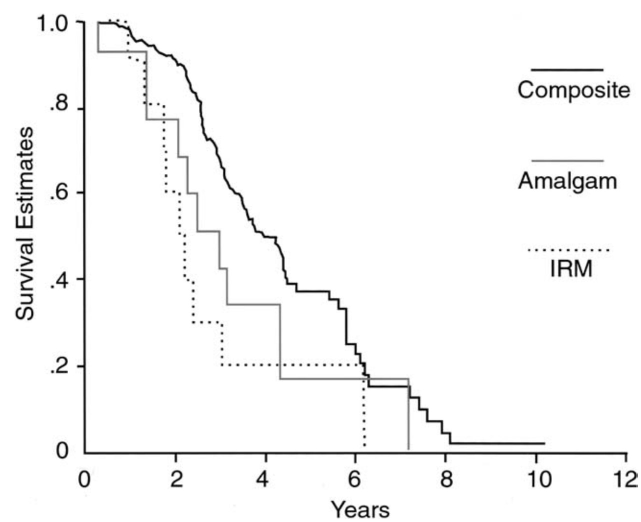

Fig. 2. Kaplan-Meier survival curves according to types of restoration.

resulting in a failure rate at tooth loss of 6.36% over an observation period of 6 months to 10.2 years.

The descriptive data of independent variables and the relationship to survival outcome using a log-rank test are presented in Table I. Patient age, gender, location, and the existence of opposing dentition and adjacent teeth were not significantly associated with tooth survival. The variables that had a significant association with survival were the amount of remaining tooth structure (P=.0003) and types of restorative materials (P=.0083).

The results of the Kaplan-Meier analysis in terms of the 1-, 2-, and 5-year estimated survival probability, the median survival time of these 2 potential factors, and of the overall findings are presented in Table II. Graphs representing the survival curves of these 2 factors are presented in Figures 1 and 2. Overall survival estimates of endodontically treated teeth at 1, 2, and 5 years were 96%, 88%, and 36%, respectively; median survival time (95% confidential interval) was 3.7 years (2.9 to 4.5 years). Median survival times increased to more than 7.9 years and 4.4 years (2.9 to 6 years) in teeth with remaining tooth structure Types I and II, respectively; and 4.2 years (3.7 to 4.8 years) in teeth restored with composite regardless of Type. At the 1-year survival estimate, survival rates of higher than 90% were found in all groups. At the 2-year survival estimate, the survival rates varied from 60% to 95%. The survival estimates of teeth with remaining tooth structure Types I, II, and III were 95%, 91%, and 80%, respectively; while those of direct resin composite, amalgam, and reinforced zinc oxide and eugenol with polymethacrylate (IRM) restorations were 90%, 77%, and 60%, respectively. At the 5-year survival estimate, survival rates of lower than 50% were found in all groups except teeth, with Type I remaining tooth structure having a survival estimate of 78%.

DISCUSSION

The results of this retrospective, observational study based on the historical data that was available in the dental records or by patients' report was verified by patient examination at the last follow-up visit for the current condition of the teeth. The study limitations included the fact that the number of teeth in each group of study variables was not well distributed and the observation periods were also unequal. However, analyses using the Kaplan-Meier method made it possible to manage these limitations since the survival probability is calculated each time a failure occurs.[37]

The evaluation of treatment outcome as failure was indicated by the incidence of tooth changes, rather than by the incidence of tooth loss. This is due to the fact that early detection of negative findings in tooth condition provides valuable information about the factors that may be related to potential tooth loss. In addition, since tooth loss due to endodontic and periodontal failures was excluded, the data represented restorative failure.

Several variable factors potentially influencing the association of survival of endodontically treated molars without crown coverage were evaluated. The results indicated that the remaining coronal tooth structure and type of restorative material had significant associations with tooth survival. Unlike the results of some previous studies,[3,5] the existence of opposing teeth and of adjacent teeth were not related to tooth survival in this study. This may be due to occlusal reduction during endodontic treatment of teeth with thin walls of remaining coronal tooth structure that minimized the effect of having opposing teeth. Information regarding the existence of adjacent teeth alone cannot provide a true representation of the occlusal loading conditions on endodontically treated teeth or the load distribution on the remaining teeth. A report on the total number of missing teeth, in addition to the presence or absence of adjacent and opposing teeth, would have been more beneficial.

Considering only the factor of remaining tooth structure, it was found that the more of the tooth structure remained, the better the survival rate. This finding seems to be intuitive, but it is also supported by several in vitro studies where it was shown that loss of coronal tooth structure weakened teeth and resulted in lower resistance to fractures.[14,15,24] Increasing the width of the occlusal isthmus[10] or the depth of the preparation, had significant influence on tooth fracture.[11,12] A significantly higher survival rate for MO/OD preparations than MOD preparations in endodontically treated teeth restored with amalgam was reported in a 20-year retrospective study by Hansen et al.[34] Additionally, it was concluded that amalgam is an unacceptable material for the restoration of endodontically treated posterior teeth if used without cuspal overlays.[31,32,34] However, when these findings were compared with a parallel study investigating the performance of composite restorations, different results were found.[34] The survival rate of teeth with MOD restorations was equal to that of teeth with MO/DO restorations. This demonstrated that the choice of materials selected for the restoration of endodontically treated teeth plays an important role in tooth longevity.

When types of restorations were compared, direct composite restorations were shown to have the best overall performance, followed by amalgam and IRM restorations, respectively. The first-year performances of these materials, however, were not much different. As time progressed, the survival rates of amalgam and IRM restorations dropped faster than those of composite restorations (Fig. 2). One reason could be that composite is an adhesive restoration that has demonstrated better resistance to the fracture of remaining tooth structure than nonadhesive restorative materials.[28] The fatigue or continued flexure of tooth structure caused by a lack of bonding may account for higher failure in the later stages of nonadhesive materials. Even though good tooth reinforcement can be achieved by using adhesive restorative materials, there are some disadvantages. In a retrospective review of 25 vertical root fractures (VRF) in endodontically treated teeth (mean time to VRF: 54 months), Llena-Puy et al[19] reported more coronal fracture in teeth restored with amalgam than with composite, but amalgam-restored teeth took significantly longer to undergo VRF than composite and bonded amalgam teeth. Therefore, other factors, such as the amount of remaining tooth structure, should be evaluated prior to determining the type of restoration to place, if long-term tooth retention is a primary goal.

Using the Kaplan-Meier analysis, for a total observation period of 10.2 years, overall survival estimates of endodontically treated molars without crown coverage were 96% at 1 year, 88% at 2 years, and 36% at 5 years, and the median survival time was only 3.7 years. This finding indicated that the longevity of endodontically treated molars without crown placement is generally poor. However, irrespective of other variable factors, the endodontically treated teeth with Type I maximum remaining tooth structure showed the best long-term survival of 78% at 5 years. This is supported by the findings of Reeh et al[14] that endodontic treatment resulted in only a 5% reduction in the relative stiffness of a tooth, while an additional MOD preparation increased its value to 63%. Furthermore, for the restoration of teeth limited to the endodontic access opening only, restored with amalgam[30] and/or a bonded restoration, this treatment was shown to have similar fracture resistance when compared with unaltered teeth, in vitro.[15,24]

Only a few previous clinical studies of endodontically treated teeth have included uncrowned teeth. In a 10-year retrospective study investigating the related factors to tooth loss of 203 endodontically treated teeth including anterior and posterior teeth, Aquilino et al[3] found significant differences in relative tooth survival between crowned and uncrowned groups. The survival estimates at 5 years for crowned and uncrowned teeth were 94% and 77%, respectively. It is worth noting that direct comparisons of tooth survival to those of other reports are difficult and rarely possible, since various criteria for the evaluation of outcome, sample selection, study conditions, and methods of analysis were not standardized. In contrast, Mannocci et al[36] reported a similar performance after 3 years of service with endodontically treated premolars restored with fiber dowels and direct composite restorations and those where the treatment provided complete coverage crown. Differences in these findings were probably the consequence of study designs. The later study was a prospective study that standardized the sample selection to only premolars with Class II carious lesion and preserved cusp structure. The results provide reassurance of a successful use of composite restorations in endodontically treated teeth without crown placement. However, long-term performance of these types of restorations requires further investigation.

This study classified the types of remaining tooth structure according to the number of intact walls that remained, and Type I remaining tooth structure was shown to have a good tendency for long-term survival. The finding, therefore, suggests that, in a selective situation of endodontically treated molars with restorative needs limited to the sealing of conservative endodontic access only, a tooth can be restored successfully for an extended period of time using composite materials. Further prospective study regarding the clinical performance of endodontically treated teeth with direct restorative materials will provide additional data to support the validity of the restorative treatment decision, including the cost-effectiveness of care.

CONCLUSIONS

Of the 220 uncrowned, endodontically treated molars, 101 teeth were found to have some changes over an observation period of 6 months to 10.2 years. Within limitations of this study, the following conclusions were drawn:

1. Overall survival rates at 1, 2, and 5 years were 96%, 88%, and 36%, respectively.
2. The remaining coronal tooth structure and types of restorative material had significant association with tooth survival.
3. Endodontically treated molars with maximum tooth structure remaining after endodontic access can be restored without crown placements with a fair long-term survival, irrespective of type of direct restoration material.
4. Intermediate restoration of endodontically treated molars with direct composite demonstrated better clinical performance than amalgam and IRM.

The authors thank Assistant Professor Dusit Sujirarat, Deputy Head, Department of Epidemiology, Faculty of Public Health, Mahidol University, for his help with the statistical analysis.

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0022-3913/$30.00

doi:10.1016/j.prosdent.2004.11.001

Noteworthy Abstracts of the Current Literature

Long-term treatment outcomes in edentulous patients with implant overdentures: The Toronto Study
Attard NJ, Zarb GA. *Int J Prosthodont* 2004;17:425-33.

Purpose. Few long-term studies on overdentures report both implant and prosthodontic outcomes. The aim of this prospective study was to report long-term prosthodontic- and implant-related treatment outcomes of patients treated with design-specific implant-supported overdentures.
Materials and Methods. Between 1982 and 1992, 45 consecutively treated patients received a total of 47 overdentures (42 mandibular and maxillary) supported by Brånemark implants. Prospective clinical and radiographic data were collected over the observation period; this study presents the most recent treatment outcomes.
Results. Thirty patients (mean age 70 years) with 32 prostheses attended the final recall visit, with 67% of patients followed for 15.53 years (range 10 to 19 years). Six implants failed, and the prosthetic plan and implant cumulative survival rates were both in excess of 90%. Mean marginal bone loss around implants after the first year of loading was small (0.05 mm/year), although the individual variation was high. Linear regression analysis of bone loss indicated that gender, bicortical stabilization, bone quality, and healing time were predictors of bone loss for the first year of loading but not for the ensuing years. Prosthetic maintenance included fractured components, denture relining, and replacement of prostheses. On average, the longevity of overdenture prostheses was 12 years, and laboratory relining was necessary every 4 years.
Conclusion. This study confirmed the long-term outcome success of patients treated with design-specific overdenture prostheses supported by Brånemark implants. However, prosthetic maintenance was required, a fact that should be discussed with patients prior to treatment.—*Reprinted with permission of Quintessence Publishing.*