Long-Term Treatment Costs Associated with Implant-Supported Mandibular Prostheses in Edentulous Patients

Nikolai J. Attard, BChD, MSc, PhD[a]/George A. Zarb, BChD, DDS, MS, MS, FRCD(C)[b]/Audrey Laporte, MA, PhD[c]

Purpose: The study's aim was to report long-term costs in edentulous patients treated with mandibular implant-supported prostheses. ***Materials and Methods:*** Ninety patients were divided into four groups based on the type of implant prosthesis (fixed or overdenture) and treatment year. Records were obtained from dental charts, and an economic analysis from the patient's perspective was conducted. Clinical time associated with various procedures was measured and applied to the four groups. Salary rates by age, occupation, and gender were used to value patients' time. Direct clinical and time costs over 10 years were converted to 2002 Canadian dollars using the Consumer Price Index and discounted at a 3% rate. A sensitivity analysis at an equal salary rate was carried out to test the robustness of the time costs. ***Results:*** Initial treatment and maintenance costs over the observation period were significantly higher for fixed compared to overdenture prostheses. A significant improvement in maintenance costs for the first patient group treated with fixed prostheses was observed over the follow-up period. Longer term (15 years) treatment costs for the initial two groups were significantly higher for the fixed group. The sensitivity analysis at an equal salary rate demonstrated the same trend: Time costs were significantly higher for the fixed groups. ***Conclusion:*** Long-term treatment costs indicated that the mandibular overdenture was a less expensive treatment compared to the fixed implant prosthesis. *Int J Prosthodont 2005;18:117–123.*

Although osseointegration has expanded the scope of treatment in edentulous patients, to date, long-term studies on patient- and clinician-mediated outcomes are relatively sparse in the literature. Implant-based treatment outcomes for edentulous patients have been in vogue for more than 20 years, yet there are still areas that have not been adequately addressed.[1,2] For example, the long-term cost implications of implant treatment for patients remain a critically important but understudied area of research.

Previous attempts at investigating the associated maintenance burden of implant prostheses have evaluated and measured the prosthodontic maintenance and, to a lesser extent, the associated clinical time.[3–6] Studies linking prosthodontic maintenance and clinical time have been identified in the literature as an important requirement to evaluate the effectiveness of a treatment approach.[7] For example, it was suggested that overdentures might not be cost effective because more maintenance and complications are observed in patients treated with removable prostheses. However, the generalizability of these studies is limited by nonstandardized patient inclusion and treatment protocols that led to a group of nonhomogeneous patients.[8–11] Studies that have attempted to directly evaluate the treatment costs of implant-supported prostheses are limited by short observation periods and inclusion of

[a]*Research Fellow, Department of Prosthodontics, Faculty of Dentistry, University of Toronto, Ontario, Canada.*
[b]*Professor and Head of Prosthodontics, Faculty of Dentistry, University of Toronto, Ontario, Canada.*
[c]*Assistant Professor of Health Economics, Department of Health Policy, Management and Evaluation, Faculty of Medicine, University of Toronto, Ontario, Canada.*

Correspondence to: *Dr Nikolai J. Attard, Department of Prosthodontics, Faculty of Dentistry, University of Toronto, 124 Edward Street, Toronto, Ontario M5G 1G6, Canada. e-mail: njattard@maltanet.net*

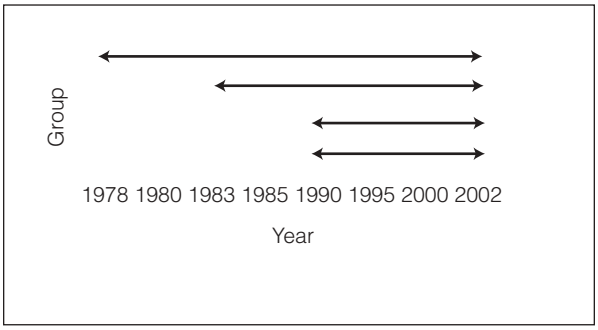

Fig 1 Treatment year and obseration period.

different prosthetic treatment plans.[10,12–15] Interestingly, a cost-analysis report[15] indicates that the direct costs with unsplinted mandibular overdentures are higher than those of conventional dentures; inclusion of indirect costs actually reduces the cost ratio, making the overdenture an attractive treatment. This underscores the need for calculating all costs.

However, to arrive at meaningful conclusions, long-term observation of patients treated with implant-supported prostheses is required. In a previous study on edentulous patients, the authors report that the mandibular overdenture appears to be more cost effective than the fixed alternative.[16] Although the results in that study were clear, shortcomings were identified, limiting the generalizability of the conclusions. The number of complications, of a surgical and prosthodontic nature, suggested that a learning phase was present with the patients. This warranted a further study to investigate whether the burden of treatment costs is lessened once the surgical and prosthodontic techniques are established. The authors therefore conducted a study on edentulous patients treated with mandibular implant-supported prostheses to investigate if the long-term treatment costs improved once the surgical and prosthodontic protocols were routinely established. The analysis was conducted from the patient's perspective, as these clinical procedures were not covered under public or private health insurance plans for these particular patient groups. In most cases, the patient bore the treatment costs through direct out-of-pocket payments at the point of service, underscoring the merits for such an approach in the economic analysis.

Materials and Methods

The four groups of edentulous patients used in this analysis were:

- Group 1: 25 patients treated with fixed mandibular prostheses
- Group 2: 25 patients treated with mandibular overdentures
- Group 3: 20 patients treated with fixed mandibular prostheses
- Group 4: 20 patients treated with mandibular overdentures

The first two groups (1 and 2) were treated prior to 1990, when the surgical and prosthetic protocols were being established, and will be referred to as "pioneer groups." In contrast, the latter two groups (3 and 4) were treated when the protocols were established and routinely prescribed (Fig 1). All patients were treated surgically ad modum Brånemark at the Implant Prosthodontic Unit, University of Toronto. A mandibular fixed prosthesis usually required a mean of five implants placed between the mental foramina. For overdenture prostheses, two implants were placed in that same site; however, some patients received three implants.

Prosthesis fabrication followed prosthetic principles described previously.[17,18] Briefly, a 12-unit fixed prosthesis with posterior cantilever segments was fabricated of metal alloy and stock denture teeth. The mandibular overdenture prostheses were supported with a cast gold alloy ovoid Dolder bar (Cendres et Métaux). Prosthodontic staff and graduate residents under supervision carried out the prosthodontic treatment initially and in latter years provided maintenance and replacement treatment.

Patients with a regular follow-up history of at least 10 years were included in the economic analysis. The rationale for this was the fact that patients were treated in different years, so follow-up length could bias the final analysis. During the last clinical visit, it was confirmed with patients that dental treatment, including maintenance, was solely provided at the Implant Prosthodontic Unit.

Furthermore, edentulous patients who received implant-supported prostheses in 2002 to 2003 were identified, and the clinical time for the prosthetic procedures was recorded. In all cases observed, patients planned for overdentures and fixed prostheses received two and five Brånemark implants, respectively, in the anterior mandible. The nature of the prosthodontic procedure was recorded, and the clinical time required for the event was measured by the clinician by means of a stopwatch. The clinical time was measured from when patients presented in the clinic until their departure with the implant-supported prosthesis or an interim prosthesis. The mean time measured was then applied to different procedures received by patients in the four groups.

The following data were collected:

1. Patient demographics: Gender, age at stage-one surgery, and occupation. Patients were categorized

into four occupational groups: *(1)* professionals; *(2)* nonprofessionals (ie, patients performing unskilled labor); *(3)* homemakers; and *(4)* retirees. The latter patients were considered retired as noted in the chart and confirmed at the last clinical visit. If patients reported a change in their occupational status (eg, from worker to retired patient), the age when the new status was initiated was noted in the database to adjust the annual salary rate.
2. First year: The number and nature of the visits. This included the preoperative consultations, surgical stage, healing phase, and prosthodontic phase.
3. First-year recall to 10-year follow-up period: The number and nature of visits the patients had per year were noted. Visits were for prosthodontic maintenance and/or recall appointments.
4. The costs for the initial treatment, remakes, and maintenance. Initial treatment costs included fees for surgery (ie, operating room), hardware, and professional fees. Maintenance included costs for damaged hardware, remakes, and relines; costs for professional services by the prosthodontist, surgeon, and laboratory; and costs for the annual recall visit and billed visits required by patients.
5. Time costs were calculated by multiplying the time spent in the clinic by the mean salary rates for the patients.

The baseline year selected for this economic evaluation was 2002, as that was the last year patients were reviewed for this study. Mean wages, defined by gender, age, and occupation, were obtained from the Census of Canada, 1980 to 2001.[19–22] Unless stated otherwise in the patient's chart, retirement age was assumed to be 65 years. The national mean income for Canadians over 65 years of age was obtained from the Income Trends in Canada, Statistics Canada.[23] The income of homemakers was assessed as the mean salary for housekeepers in an attempt to value the time these patients spent in the clinic. This approach is consistent with the human capital method, which values patients' time using the forgone labor market wage.[24] The costs for every patient were converted to 2002 dollars using the Consumer Price Index (CPI), as described elsewhere.[16] Mean wages were adjusted using the mean CPI for Canada from 1979 to 2002.[25] Clinical costs (initial intervention, complications, and recalls) were adjusted using the Health CPI.[25] The treatment costs in 2002 Canadian dollars ($CAD) were calculated as described previously.[16] As the present study compared two interventions that involve a series of expenditures over time, the "time value of money" must be accounted for.[24] That is, a dollar spent today is a greater expense than a dollar spent in the future. Briefly, the treatment costs in 2002 $CAD comprised:

1. Total costs = (total clinical costs) + (time costs)
2. Time costs = (salary rate/hour) × (annual clinical time for care)
3. Total clinical costs = (initial treatment costs) + (maintenance costs)
4. Maintenance costs = (prosthodontic costs for work other than the first implant-supported prosthesis) + (recall costs)

Although travel costs are a component of direct patient costs in economic evaluations conducted from the patient's perspective, they were excluded from this analysis to avoid overstatement of current costs. While a few patients from group 1 traveled long distances to receive treatment at the facility, most patients currently have ready access to prosthodontic service providers. Also, the method of traveling was not recorded for the patients and therefore could not be used as part of the measurements.

Analyses of the data were performed with the aid of the SPSS statistical package (SPSS). The tests were: chi-square, Mann-Whitney *U,* Kruskal-Wallis, and Wilcoxon signed ranks. Statistical significance was set at $P < .050$.

Results

Sociodemographic and Other Variables

No statistically significant differences between the four groups were present with respect to gender, marital status, medical status, or profession (chi-square tests, $P > .050$). A significant difference in age at the time of implant placement was observed between groups. The patients in group 1 were significantly younger than those in group 4 when treated (Mann-Whitney *U* test, $P = .002$). The patients in group 1 were followed for the longest observation period. The recent groups (3 and 4) were both followed for a minimum of 10 years, allowing for direct comparison of maintenance requirements of the four groups up to 10 years. The maintenance requirements for groups 1 and 2 were compared for at least 15 years, as per their additional follow-up (Fig 1 and Table 1).

Initial Treatment Costs

As to be expected, there were significant differences in the costs for the initial prosthodontic work. Patients in the fixed groups (1 and 3) paid more for their treatment, as it involved more implants and a more extensive prosthodontic treatment plan (Mann-Whitney *U* test, $P < .050$). However, there were no cost differences between the fixed groups (Mann-Whitney *U* test, $P > .050$). The pioneer overdenture group (2) paid the least for the initial treatment (Mann-Whitney *U*

Table 1 Means ± Standard Deviations of Continuous Descriptive Variables (in y)

Group*	Age at implant surgery†	Age at last recall visit	Length of follow-up†
1	49.45 ± 10.13	70.16 ± 10.17	20.67 ± 1.34[a]
2	54.17 ± 11.14	69.50 ± 10.63	15.64 ± 2.38[b]
3	56.05 ± 10.87	67.95 ± 9.73	12.40 ± 2.28
4	60.50 ± 4.47	70.60 ± 4.24	10.95 ± 0.76

*See Materials and Methods section for group descriptions.
†Kruskal-Wallis test and Mann-Whitney *U* test; significant at $P < .050$.
a = group 1 > groups 2 to 4 b = group 2 > groups 3 and 4

Table 2 Mean ± Standard Deviation Costs for the Pioneer Fixed Group (1 to 10 y and 11 to 20 y) and the Other Three Groups (1 to 10 y)*

Group†	Maintenance costs	Prosthodontic costs	Recall costs
1	2,736.76 ± 1,318.95[a,b]	2,177.58 ± 1,041.44[a,b]	559.18 ± 495.83[a,b]
2	802.60 ± 477.33[c,d]	512.43 ± 494.87[c,e]	290.16 ± 130.35[c,d]
3	1,259.10 ± 1,050.29[f]	963.38 ± 1,036.87[f]	295.72 ± 93.25[f]
4	528.49 ± 386.26	338.44 ± 413.84	190.05 ± 98.77
1b	1,250.84 ± 1,042.78[g,j,l]	1,010.54 ± 1,025.29[h,j,l]	240.30 ± 447.90[i,k,m]

*In 2002 Canadian dollars; costs discounted at a 3% rate.
†See Materials and Methods section for group descriptions.
Wilcoxon signed ranks test:
a = $P < .050$, group 1 > group 1b
Mann-Whitney *U* test:
b = $P < .050$, group 1 > groups 2 to 4
c = $P > .050$, groups 2 to 3
d = $P < .050$, group 2 > group 4
e = $P > .050$, groups 2 to 4
f = $P < .050$, group 3 > group 4
g = $P > .050$, groups 1b to 2
h = $P < .050$, group 1b > group 2
i = $P < .050$, group 2 > group 1b
j = $P > .050$, groups 1b to 3
k = $P < .050$, group 3 > group 1b
l = $P < .050$, group 1b > group 4
m = $P > .050$, groups 1b to 4

test, $P < .050$; group 2 < groups 1, 3, and 4), probably because the patients were participating in a study and might have been offered a lower initial cost; the more recently treated groups had their intervention when the technique was established and offered at regular costs.

Maintenance Costs

As the pioneer fixed group was followed for a mean of 20 years, the group's costs could be dichotomized into two decades. This allowed direct comparison between the two decades for group 1 itself and for comparison of the maintenance costs over the second decade with the other three groups (Table 2). Overall observation of the maintenance costs demonstrated statistically significant differences between the four groups. Group 1 had the highest maintenance costs compared to the other three groups. Pairwise comparison of the other three groups showed no significant differences between group 2 and groups 3 and 4. Group 2 required more maintenance than group 4 but less than group 3. Comparison of groups 3 and 4 indicated that the fixed group had higher maintenance costs than the overdenture group. Maintenance costs were further subdivided into prosthodontic maintenance and recall visit costs. Group 1 had the highest prosthodontic and recall costs. The results for the prosthodontic costs indicated that group 2 was not statistically different from groups 3 and 4. The latter groups differed, with group 3 having higher prosthodontic maintenance costs. The recall costs were similar. No significant differences were present between groups 2 and 3; however, both groups had higher recall costs than group 4.

Of note, maintenance costs, including prosthodontic and recall costs, decreased significantly over the second decade for group 1. No differences in the maintenance costs, except for recalls, were present when group 1b (pioneer fixed group, 11 to 20 years) was compared to group 3. Prosthodontic costs were still significantly higher for group 1b compared to both overdenture groups (2 and 4). The recall costs were significantly higher for group 2, and this resulted in cumulative maintenance costs that were not statistically different from those in group 1b. However, maintenance costs were still significantly higher for group 1b compared to group 4. Similar trends were observed for the total clinical costs, with group 2 having paid the lowest clinical costs. The time cost results showed

Table 3 Total Costs (Mean ± Standard Deviation) for Groups 1 to 4 (1 to 10 y)*

Group†	Total clinical costs	Total costs	Time costs	Salary rate/h	Time costs 2
1	10,722.88 ± 2,188.97[a]	11,492.32 ± 2,685.66[a]	769.45 ± 1,051.84[b,c]	21.49 ± 21.14[h,i]	662.30 ± 170.78[m]
2	3,078.49 ± 934.89[d]	3,581.12 ± 1,185.10[d]	502.63 ± 477.60[e,f]	20.39 ± 14.36[j,k]	430.96 ± 139.83[n]
3	8,880.27 ± 1,644.73[g]	9,660.51 ± 1,896.71[g]	780.24 ± 558.85[g]	30.75 ± 19.87[l]	512.04 ± 162.05[o]
4	5,137.69 ± 460.94	5,508.91 ± 565.64	371.22 ± 176.35	18.99 ± 11.55	392.67 ± 126.91
Overall significance‡	.001	.001	.006	< .001	< .001

*In 2002 Canadian dollars; costs discounted at a 3% rate.
†See Materials and Methods section for group descriptions.
‡Kruskal-Wallis test.
Mann-Whitney *U* test:
a = $P < .050$, group 1 > groups 2 to 4
b = $P > .050$, groups 1 to 3
c = $P < .050$, group 1 > groups 2 and 4
d = $P < .050$, group 2 < groups 3 and 4
e = $P < .050$, group 2 < group 3
f = $P > .050$, groups 2 to 4
g = $P < .050$, group 3 > group 4
Time costs 2 = recalculated with mean salary of CAD$ 18.99 across the four groups:
h = $P > .050$, group 1 to groups 2 and 4
i = $P < .050$, group 1 < group 3
j = $P < .050$, group 2 < group 3
k = $P > .050$, groups 2 to 4
l = $P < .050$, group 3 > group 4
m = $P < .050$, group 1 > groups 2 to 4
n = $P > .050$, groups 2 to groups 3 and 4
o = $P < .050$, group 3 > group 4

Table 4 No. of Patients Requiring Prosthodontic Maintenance Events (1 to 10 y)*

Type of maintenance	Group 1	Group 2	Group 3	Group 4
Conversion of prosthetic plan	6†	0	2†	0
Damaged framework screws	8	1	7	0
Damaged abutment screws	8	1	6	0
Fractured framework (fixed prosthesis or Dolder bar)	7	1	1	0
Fractured denture teeth	9	2	2	2
Fractured opposing denture	0	3	0	2
Damaged clip mechanism	0	5	1	0
Loose framework	1	3	2	0
Laboratory reline of opposing denture only	7	7	8	5
Laboratory reline of overdenture only	1‡	1	0	7
Prosthesis adjustments	16	17	7	6
Remake of implant prostheses	27	5	4	3
Remake of new opposing denture	13	7	5	3
Mean ± standard deviation clinical visits/y (after first y)				
Maintenance	1.42 ± 0.98	1.02 ± 0.89	0.93 ± 1.16	0.77 ± 1.03
Recall	0.66 ± 0.21	0.57 ± 0.23	0.45 ± 0.23	0.39 ± 0.24
Total	2.09 ± 1.00	1.59 ± 0.81	1.37 ± 1.15	1.16 ± 0.98

*See Materials and Methods section for group descriptions.
†Patients who had their fixed prosthesis plans converted to overdentures because of implant failure or adverse biomechanical loading.
‡Relining of overdenture.

higher costs for the fixed groups (1 and 3) compared to the overdenture groups (2 and 4). Group 4 had the lowest time costs of the four groups; however, no statistically significant differences were observed between the overdenture groups (Table 3).

The first two groups treated (group 1 = 25 patients, group 2 = 22 patients) were followed for a further 5 years. All costs for these two groups were calculated, and the same trends observed for the previous 10 years were still valid: All results showed statistically significantly higher costs for the fixed group compared to the overdenture group (Mann-Whitney *U* test, $P < .050$)

Type of Visits and Nature of Prosthodontic Maintenance

No significant differences between the four groups were observed for the total number of visits in the first year. Further analysis of the visits based on the nature of the visits yielded no differences for the presurgical consults, number of visits during the fabrication of the prostheses, or number of visits for postinsertion adjustments (Kruskal-Wallis test, $P > .050$). Analysis of the average visits per year between 1 and 10 years (Table 4) indicated that group 1 had more visits during the timeframe compared to the other three groups.

The same observation was made for the maintenance visits. Both were statistically significant (Kruskal-Wallis test, $P < .050$). The same group (1) also had more recall visits compared to the recent groups (Mann-Whitney *U* test, $P < .050$), but not compared to group 2. On the other hand, group 2 had globally more visits and recall visits compared to groups 3 and 4 (Mann-Whitney *U* test, $P < .050$). No statistical difference was observed for the maintenance visits. With respect to the recent groups, no difference was observed for any category of visits (Mann-Whitney *U* test, $P > .050$).

Sensitivity Analysis of Time Costs

The salary rate per hour for the four occupation categories revealed statistically significant differences, with professionals earning the most (professionals $CAD 42.97 ± 26.96, nonprofessionals $CAD 22.54 ± 8.96, homemakers $CAD 16.88 ± 4.66, and retirees $CAD 10.83 ± 1.50; Kruskal-Wallis test and Mann-Whitney *U* test, $P = .001$). There was also a significant difference in the mean salary rate between the treatment groups (Table 3). To investigate the possibility that time costs based on different mean wages were driving the higher reported time costs for the fixed groups, these costs were recalculated using the lowest salary rate ($CAD 18.99/hour; group 4) for all groups. The adjusted time cost still reflected the same trend: Group 1 had the highest time costs, and overall, patients with fixed prostheses had higher times costs than those with overdentures.

Discussion

This study investigated the long-term costs associated with mandibular implant-supported prostheses from the patient's perspective. The results are important for a number of reasons: They are based on long-term observations in patients treated with two particular designs, which provided a more comprehensive picture of the cost burden to patients. Our cost estimates are probably not significantly influenced by the exclusion of travel costs, as implant treatment is now widely available in the private sector, and it is therefore unlikely that a patient would be required to travel long distances to receive treatment. The total costs during the observation period indicated that the pioneer fixed group had the highest treatment costs compared to the other three groups. The same results were seen for the global clinical costs. The pioneer overdenture group had the lowest initial treatment costs compared to the other groups. No significant differences were present for the fixed groups, yet both were significantly more expensive than the overdenture groups.

What is more relevant from the patients' perspective is what happens after the initial treatment is concluded. In other words, what maintenance costs can be expected for these implant-supported prostheses? Comparisons of the recent groups indicated that the fixed group had more maintenance costs than the overdenture group. In fact, both prosthodontic and maintenance costs were significantly higher for the fixed group.

The long-term follow-up period of the pioneer fixed group allowed for a direct comparison of the maintenance costs for the same group of patients over two decades. The results demonstrate that the prosthodontic maintenance costs for the pioneer fixed group were lower in the second decade. Although the costs were the same as those for the recent fixed group, the pioneers' prosthodontic costs were still higher than those of the two overdenture groups, indicating that patients can expect to incur higher maintenance costs with a fixed prosthetic plan.

The approach in this study was based on the human capital method, the dominant methodology used in the literature to value patients' time using the market wage rate.[24] However, the methodology for the measurement of clinical time in the present study deserves special consideration. The use of recently measured clinical time for diverse prosthodontic procedures and its subsequent use for similar events that happened previously can be criticized and viewed as a limitation of this research. In fact, it is probable that the present study may have underreported the clinical time for the pioneer groups because at that time, clinicians were still learning the surgical and prosthodontic techniques, including management of complications. Nevertheless, it is reassuring to observe that the clinical time recorded was similar to that reported by other authors, suggesting that the results could be viewed as a tangible measure of time.[3,4,6,13,26] Even excluding the time costs, however, the general conclusion that the overdenture prosthesis was a more cost-saving approach for rehabilitating mandibular edentulism holds.

Inclusion of four groups and direct comparison of the two time periods of the pioneer fixed group allowed us to conclusively understand if a learning curve was present. Indeed, a learning curve was present, with the pioneer groups having more maintenance over the same period of observation. The amount of required maintenance decreased over the 10 years of observation for the pioneer groups and in particular for the fixed group (difference in maintenance costs pioneer vs recent groups = 62% improvement; difference within group 1, first vs second decade = 54% improvement). This is probably due to the refinement of prosthetic techniques after the first phase. The maintenance costs of the pioneer groups were still significantly higher for the

fixed group, with the prosthodontic maintenance contributing significantly to this result.

The cost analysis of the treatment outcomes with implant-supported mandibular prostheses clearly indicated that the fixed prosthesis design was more expensive to fabricate and maintain over the 10 years of observation. Although the maintenance costs for the fixed pioneer group were lower in the second decade, the same trends for maintenance costs for the pioneer groups were present during the subsequent years of observation. The results highlight the fact that the overdenture approach, at least with a resilient bar retention mechanism, was indeed a less expensive approach to rehabilitating edentulous patients seeking implant-supported mandibular prostheses.

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