The Cost of Dental Implants as Compared to That of Conventional Strategies

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The effectiveness of dental implants is widely studied, especially in terms of their clinical outcomes. However, from the policymaker's point of view, variables other than safety and efficacy, such as the costs and effectiveness of dental implants as compared to other treatment alternatives, are vital in decision making. This paper compares the costs of different treatment strategies in a randomized clinical trial in patients with resorbed mandibles and persistent problems with their conventional dentures: treatment with a mandibular overdenture on permucosal dental implants, an overdenture on a transmandibular implant, new dentures after preprosthetic surgery, and new dentures only. Data were gathered on an individual patient level to gain insight into specific cost episodes. Direct costs were subdivided into labor, material, technique, and overhead. Data concerning these components were gathered during the consecutive treatment phases in the first year. Results show that the resources used to treat a patient with an overdenture supported by a transmandibular implant are seven times those of a complete new set of dentures. Comparison of the cost ratio of an implant-retained overdenture supported by permucosal implants and conventional new prostheses proves less unfavorable: 1:3. New dentures after preprosthetic surgery are almost as expensive as treatment with permucosal implants.
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Key words: costs, dental implants, dentures

Health care costs have grown in many Western societies since the 1980s. Cost containment remains a dominant theme within the health care sector, and reliable information concerning the costs of alternative treatment strategies is therefore relevant. The various options for treating edentulousness are compared in this report.

Dental implants were developed as an alternative means of support for conventional dentures, and their effectiveness has been well established during the last decade. Growing evidence of this effectiveness calls for research into the costs and outcomes of this treatment. The main criterion for clinical success seems to be survival,[1–7] although other objective criteria, such as Gingival Index, Plaque Index, pocket depth, and mobility of the implant, are also frequently described.[1,8–11] In a number of other publications, the psychosocial effects of dental implants have been considered.[12–16] Overall, these studies show considerable improvement in the psychologic wellbeing of patients treated with dental implants. Only one article is known to have assessed costs.[17]

The purpose of this study was to compare real treatment costs during the first year of overdentures supported by dental implants versus conventional strategies.

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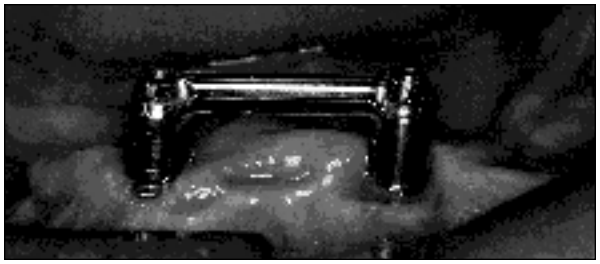

Fig 1 Two Brånemark implants with a bar attachment.

Fig 2 Two IMZ implants with a bar attachment.

Materials and Methods

Patient Selection. A randomized clinical trial was conducted at the Department of Oral and Maxillofacial Surgery and Maxillofacial Prosthodontics (University Hospital of Groningen) and the Department of Oral and Maxillofacial Surgery (University Hospital of Nijmegen). Treatment with implant-retained mandibular overdentures on two permucosal implants was compared to treatment with a mandibular overdenture on a transmandibular implant and to two conventional treatments with a new mandibular denture, one after preprosthetic surgery and one without surgery. All patients received a new maxillary denture.

Four possible treatment alternatives were included. Surgery for permucosal implants (PI) was performed under local anesthesia. Two different, two-phase implant systems were used: the Brånemark system (Nobel Biocare, Goteborg, Sweden), a titanium screw-type cylinder, and the IMZ system (Friedrichsfeld, Mannheim, Germany), a titanium cylinder with titanium plasma-spray coating. During the first phase, implant placement, two implants were interforaminally placed in the mandible under local anesthesia. The mean duration of the implant operation was 73 minutes. After this operation, the patient was seen two times for 15-minute check-ups. Patients were not allowed to wear the conventional mandibular denture during the first 2 weeks. After initial wound healing, the denture was relined, and a soft diet was prescribed. The abutment connection took place after a healing period of 3 to 6 months. At that time, the titanium abutments were connected to the implants. The mean duration of this second operation was 41 minutes, and it was followed up by one routine 15-minute check-up. For both implant systems, an implant- and tissue-supported overdenture with a single-bar attachment was used (Figs 1 and 2).

Transmandibular implants (TMI) (Krijnen Medical, Beesol, The Netherlands) were placed extraorally,[3] and surgery was performed under general anesthesia. Mean operating duration, including the impression for the superstructure, was 131 minutes. The superstructure consisted of a triple-bar construction with cantilever extensions (Fig 3). The patient was examined three times (60 minutes total) before the superstructure was placed.

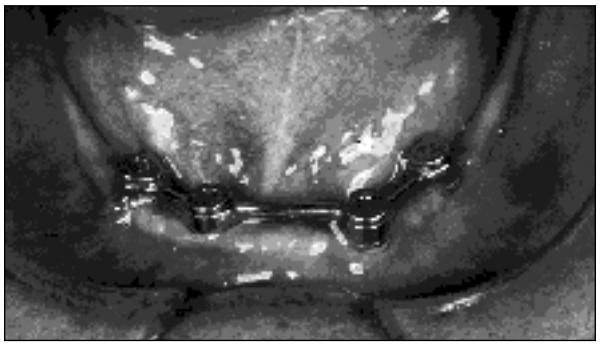

Fig 3 A transmandibular implant placed according to Bosker.[3]

Preprosthetic surgery (PPS) took place under general anesthesia. Thirty patients were treated surgically by interforaminal vestibuloplasty and deepening of the floor of the mouth. The operation itself lasted 90 minutes, and 120 minutes more were needed for diagnostics, follow-up, and relining of the prosthesis. The group of patients which received new dentures did not have any surgery. In all groups, dentures were fabricated with an optimal fit and according to the balanced occlusion principle.

In total, 240 patients were randomly assigned to one of these four groups. For the economic evaluation, two separate trials were combined in the ADIOS (Academic Dutch Implant Overdenture Study) group. In Nijmegen, three groups of 30 patients were treated either with mandibular overdentures, with overdentures supported by permucosal implants, or with conventional new dentures. All of these patients had a maximum mandibular bone height of 14 mm. In Groningen, selection was made based on the mandibular bone height. For the

Table 1 Patient Characteristics at Baseline

Patient characteristics	Treatment group			
	Transmandibular implants (n = 30)	Permucosal implants (n = 89)	Preprosthetic surgery (n = 28)	New dentures (n = 89)
Age (y)	53	55	53	57
Gender (%)				
Males	28	23	37	29
Females	72	77	63	71
Time edentulous in mandible (y)	21	22	20	23
No. of mandibular dentures	3.5	2.8	2.3	2.8
Mean age of mandibular denture (y)	6.4	7.2	8.2	6.9

group of patients with mandibular bone height above 15 mm, three treatment options were available: overdentures supported by permucosal implants, new dentures after preprosthetic surgery, or conventional new dentures. For the patients with a low bone height (8 to 14 mm), preprosthetic surgery to obtain an increase of the denture-bearing area would be insignificant.[18] Thus, for the group needing mandibular prostheses only, two treatment options were available: overdentures supported by permucosal implants or conventional new dentures. The whole concept, ordered by the National Health Insurance Council of the Netherlands, resulted in an uneven distribution of patients. Nevertheless, it had several advantages: similar treatment procedures were used and evaluated and a larger research population was established.

Patients included in this study all had severely resorbed mandibles and persistent problems with their conventional dentures. They were referred to a university clinic by general practitioners. The criteria for inclusion in this investigation were edentulousness in both jaws for at least 12 months, mandibular bone height of 8 to 25 mm, and no general contraindications for implants or surgical procedures. All subjects were informed about different treatment options, possible risks, and the method of treatment assignment. Written informed consent was required for participation in the trial. Treatment was assigned by means of a balancing procedure designed for an equal distribution of patients over the treatment groups with regard to variables that could interfere with the outcome of the study.[16,19] This pretreatment comparability was ensured by balancing all groups for age, gender, period of edentulousness in the mandible, age of the existing mandibular denture, and mandibular bone height. Table 1 shows the structure of the treatment groups and their most relevant characteristics. Only the number of dentures in the mandible differed among the various treatment groups (two-way analysis of variance [ANOVA]).

Study Design. In association with this clinical trial, a cost analysis of all different treatment modalities was performed. It was possible for patients to refuse the allocated treatment, and nine did. For these patients, the "intention to treat" principle was applied, which means that patients were evaluated in the treatment group to which they were originally assigned regardless of their actual treatment. However, for the cost analysis these patients' refusal was irrelevant, because people who were not treated did not generate any costs. The same principle holds for patients lost through attrition: as long as they did not show up at the dental clinic, no treatment costs accrued. If effects would have been taken into account, exclusion of these patients would have been a probable source of bias.

The integral cost analysis was based on data related to actual costs, and not on data concerning fees. Fees represent revenue for the provider and in most cases do not reveal actual costs. Since the study was concerned with actual costs, and not fees, patients were followed through the treatment process during the first posttreatment year. Detailed hospital data were collected for each patient. Costs were subdivided according to the categories of labor, equipment, technique, and overhead during the different treatment phases: examination, implant operation, abutment operation, prosthodontic treatment, follow-up examinations, and complications through 1 year after treatment. A procedure comparable to the Resource-Based Relative Value Scale[20,21] was used to calculate costs. Cost components were divided according to physicians' labor and practice expenses. A conversion factor was not used since for all components actual costs were assessed completely and not relative to other medical procedures.

The cost of labor was based on a recording of treatment time at the individual patient level. Actual costs were then determined based on the gross salary of the dental staff. Costs of labor can be divided into

Table 2 Total Treatment Time by Each Professional and Costs for Each Treatment Group

	Treatment group							
	Transmandibular implants		Permucosal implants		Preprosthetic surgery		Complete dentures	
	Time	Cost ($)	Time	Cost ($)	Time	Cost ($)	Time	Cost ($)
Dental surgeon	4 h 06	250	3 h 34	217	3 h 30	213	—	—
Nurses	6 h 22	174	6 h 07	136	3 h 00	82	—	—
Anesthetist	2 h 41	163	—	—	0 h 30	30	—	—
Assistant anesthetist	—	—	—	—	1 h 30	64	—	—
Administrative nurse	0 h 30	12	0 h 40	15	0 h 15	9	—	—
Prosthodontic procedure								
Prosthodontist	4 h 38	197	4 h 40	200	3 h 58	168	4 h 06	175
Assistant to prosthodontist	4 h 38	100	4 h 40	102	3 h 58	84	4 h 06	87
Total	896		670		650		272	
95% confidence interval	875–917		648–692		616–684		248–296	

surgical and prosthodontic costs. The estimate of labor costs included the duration but not the intensity of the treatment.

Practice expenses were subdivided according to material, hospital, and overhead costs. Material included the costs of the dental implants, the new conventional dentures, the abutments, and so forth. All of the different cost components were gathered on an individual patient level as well. At the hospital level, a variety of diagnostic tests (blood tests, radiographs) were performed on patients undergoing general anesthesia (ie, the TMI group and those patients who received preprosthetic surgery [PPS]). Information on whether the test was performed on individual patients was not always recorded. The costs of diagnostic tests were estimated from the treatment protocol. Other hospital costs were generated because patients who received a transmandibular implant or preprosthetic surgery were required to stay in the hospital for 3 days. Finally, there were the overhead costs. Each treatment made use of the normal hospital facilities, and therefore incurred the following costs: reusable equipment, capital costs of the building and the inventory, consumables, laundry services, cleaning, maintenance, electricity, administration, and so forth. An estimate of the cost of floor space was made by calculating the size of the dental department and multiplying it by the historic value of office and clinical space. All other costs (laundry, cleaning, maintenance) were approximated based on hospital expenditure for the different components within the total budget. All costs originally were measured in Dutch guilders and then converted into U.S. dollars. The exchange rate in 1994 was approximately $1:Dfl1.6.

Statistical Analyses. To make the results more comprehensive, mean values are used in the tables. Differences in patient characteristics were tested by means of a two-way ANOVA with a significance level of $\alpha = .05$. For all cost data, a 95% confidence interval was calculated based on the standard error of the mean of all groups. No differences in costs relating to bone height were found.

Results

Costs of Surgical Procedures. Table 2 shows the total time spent by each different professional within treatment, and the resulting costs. Time invested by the prosthodontist and assistant does not vary significantly. In the implant groups, more time was needed to fabricate the superstructure, and the operation time was of course higher, especially for the transmandibular implant; this difference leads to pronounced additional costs.

Costs of Prosthodontic Procedure. All groups had the prosthodontic treatment performed according to a standard procedure. The permucosal implant group began prosthodontic treatment about 3 weeks after the second operation. The group of patients with a transmandibular implant had the superstructure placed within 24 hours of surgery, and the new dentures were made 2 months later. The PPS group was transferred to the prosthodontist 1 month after the vestibuloplasty. Patients who received new dentures began their treatment with the prosthodontists. Mean treatment time for the fabrication of new dentures was calculated on an individual patient level. Table 2 presents the results, including all check-ups until 6 weeks after treatment.

Other Costs. All patient groups undergoing surgery incurred costs of operating room usage. Table 3 shows the practice expenses for all treatment groups.

For the operational procedures, a standard package of diagnostic tests (including an electrocardio-

Table 3 Practice Expenses (in Dollars) Per Treatment Group

	Treatment group			
	Transmandibular implants	Permucosal implants	Preprosthetic surgery	Complete dentures
Hospital costs				
Laboratory tests	75	—	75	—
Radiographs	63	63	63	—
Electrocardiogram	18	—	18	—
Hospital room	1,500*	—	1,500*	—
Operating room				
Minimum	469**			
Maximum	1,594	434	469	—
Medication	12	12	12	—
Material costs				
Equipment	345	175	—	—
Implants	2,130	455	—	—
Prosthesis	1,475	1,220	570	575
Overhead costs	400	412	392	211
Total	6,487–7,612	2,771	3,099	786
95% confidence interval	[6,387–7,712]	[2,669–2,873]	[3,038–3,160]	[752–820]

*Average length of stay was 3 days in a university hospital.
**Due to the insurance system in the Netherlands, part of the cost of the transmandibular implant (nobody knows which) is accounted for in the bill of the operating room. The minimum cost pertains when the implant is paid largely out of this fee; the maximum cost represents the fee for a very difficult operation and almost no payment for the implant itself.

Table 4 Time and Costs of Follow-up for Each Treatment Group

	Treatment group							
	Transmandibular implants		Permucosal implants		Preprosthetic surgery		Complete dentures	
	Time	Cost ($)	Time	Cost ($)	Time	Cost ($)	Time	Cost ($)
Dental surgeon	0 h 50	55	0 h 40	33	0 h 10	11	—	—
Dentist	0 h 67	52	0 h 48	37	0 h 20	16	0 h 40	30
Dentist assistant	0 h 67	30	0 h 48	22	0 h 20	9	0 h 40	17
Dental hygienist	0 h 35	19	0 h 50	29	—	—	—	—
Total labor costs		156		121		36		47
Material		68		119		13		19
Overhead		118		77		10		28
Total costs of follow-up		342		317		59		94

gram) was used. Patients undergoing general anesthesia (TMI and PPS) stayed in the hospital for 3 days at a cost of $1,500. Medication consisted of antibiotics and analgesics. Material costs were divided according to equipment, implants, and prosthesis. Different equipment and instruments were used for each treatment modality during the surgical and prosthodontic procedures. The instrument case for the transmandibular implant was used on average for the operation of 30 patients. The total costs of an instrument case with tray including an adjustable drill guide, superstructure drill guide, several screwdrivers, drill sleeves, tap sleeves, fasteners, and lock screws are about $6,000, or $200 per patient. This does not include drills and taps ($145 per patient). The use of disposables for the permucosal implants differs somewhat for the Brånemark and the IMZ systems. The Brånemark system uses special disposables for implant patients, whereas IMZ uses the regular instrumentation of a dental surgeon. However, the resulting differences in costs per patient were not dramatic (about $50 per patient), so the average cost of both systems was used. Total costs of disposables were $175 per patient (drills, screw taps, screws, and the capital costs of a control unit).

Other material costs mainly represent those of the implants themselves, the abutments, the superstructure, and the dental prosthesis. Overhead costs were attributed to the treatment groups on the basis of total treatment time. Table 3 provides an overview of the material and overhead costs per treatment group.

Table 5 Total Cost of Treatment (in Dollars) During the First Year

	Treatment group			
	Transmandibular implants	Permucosal implants	Preprosthetic surgery	Complete dentures
Labor				
Surgery	599	368	398	—
Prosthodontics	297	302	252	262
Check-ups	156	121	36	47
Practice expenses				
Materials				
Implants	2,975	370	—	—
Instruments	199	99	—	—
Disposables	145	114	—	—
Prosthesis	631	1,220	570	575
After treatment	68	119	13	19
Overhead				
Treatment	400	412	392	211
After treatment	118	77	10	28
Hospital costs				
Hospital stay	1,500	—	1,500	—
Operating room	469–1,594	434	469	—
Diagnostic tests	168	75	168	63
Total first-year costs	7,605–8,830	3,711	3,808	1,205
95% confidence interval	7,494–8,951	3,644–3,858	3,712–3,894	1,170–1,240
Index	631–733	308	316	100

Follow-up Costs (Through the First Year). In some patients, complications greatly influenced the total treatment cost. Follow-up costs were calculated according to the number and average duration of dentist visits. In addition, material and overhead costs were accounted for as described above. In Table 4, the labor time of follow-up treatment is shown for each treatment group. Because of visits to the dental surgeon and the dental hygienist, both implant groups were significantly more expensive than the conventional treatments with respect to follow-up. In total, these costs amount to more than $300 for the first year, while follow-up treatment for patients with a new denture cost less than $100. During the first year, the average follow-up time for the implant groups was 48 minutes (PI) and 67 minutes (TMI) with the dentist and 50 minutes (PI) and 35 minutes (TMI) with the dental hygienist. This follow-up treatment included aftercare and maintenance of a healthy oral condition.

Total Costs (Through the First Year). The costs of each treatment strategy can be divided into the components of labor, material, and overhead (Table 5). The costs for the first year of treatment total between $7,600 and $8,800 for an overdenture supported by a transmandibular implant. The total cost is seven times that of treatment involving new complete dentures. Treatments with an overdenture supported by permucosal implants or new dentures after vestibular surgery are similar in terms of their cost, which is almost 3.2 times as much as new complete dentures. The higher cost of the transmandibular implant and the preprosthetic surgery result from the need for an operation under general anesthesia (hospital stay, diagnostic tests, operating room costs). Costs of aftercare were included for the first year. In these costs, failures of new dentures were included.

Sensitivity Analysis. The purpose of a sensitivity analysis is to test the validity of conclusions made over a range of reasonable values for the assumptions made in the baseline analysis. In this sensitivity analysis, the threshold values at which the conclusions about the total costs would change were calculated. A summary of the sensitivity analysis and its relation to the main analysis is shown in Table 6. The model is based on the costs for the first year. One of the most important assumptions for generalization is the survival rate. Assuming that 100% of the implants in patients in the transmandibular and permucosal treatment groups would survive, the treatment costs are $7,394 and $3,363, respectively ($822 and $375 cheaper). The other cost components do not have a significant differentiating impact on total costs between groups, with the exception of material costs. If the costs of the dental equipment necessary to use dental implants would increase by 25%, total costs of the implant groups would increase by $1,006 and $482 for the transmandibular and permucosal groups, respectively. The annual figures do not change dramatically if one or the other estimates is varied.

Table 6 Summary of the Primary Analysis (Average Costs) and the Sensitivity Analysis (Additional Costs Under Various Assumptions), in Dollars

	Treatment group			
	Transmandibular implants	Permucosal implants	Preprosthetic surgery	Complete dentures
Primary analysis	8,216	3,748	3,776	1,179
Survival of implants: +10%	822	375	0	0
Aftercare: +25%	86	79	15	24
Operating time: +25%	150	92	97	0
Material costs: +25%	1,006	482	145	148
Overhead costs: +25%	156	129	104	78
Hospital costs: +25%	665	158	534	16

Discussion

This paper has described in some detail the total treatment costs of a specific new technology: dental implants and overdenture treatment. Although few articles on this particular subject have been published in the dental literature, this information could be crucial in light of the dwindling resources for health care. With regard to labor, material, and hospital expenses, the detailed information that was collected enabled the calculation of per-patient costs. The resources used to treat a patient with an overdenture supported by a transmandibular implant could provide nearly seven patients with new complete dentures. If one compares a conventional new prosthesis with an implant-retained overdenture supported by permucosal implants, the proportion of costs becomes more favorable, namely 1:3. New dentures requiring preprosthetic surgery are almost as expensive as treatment with an overdenture supported by permucosal implants. These figures compare to those of Jönsson and Karlsson,[17] with one exception. In their study, the permucosal implant alternative was much more expensive, but this is only logical since they evaluated implants with a fixed prosthesis.

The results of the study seem rather robust. The sensitivity analysis shows that threshold values for various cost estimates, for which conclusions alter, are unrealistic. Furthermore, the confidence intervals are rather small, which suggests that collecting individual data is an accurate method to estimate costs. The relatively small standard deviations confirm the relative homogeneity of the study group. In only a very few patients were enormous costs needed to improve the oral health status. The presented data seem useful for other purposes, because the outcomes look comparable to those reported in the literature.[1,3,7,10] In the first year, a 92% survival of the implants was measured. The aforementioned studies all claimed survival rates between 89% and 96%.

The method used for cost analysis closely resembles the Resource-Based Relative Value Scale adopted by the U.S. Congress in 1989. Such a system provides information that accurately reflects the resource cost required to deliver a service. Although this method was not used in the Netherlands for determination of reimbursement levels, it provides a better understanding of true costs than do tariffs. The relative comparison of different types of maxillofacial procedures becomes well-founded. The cost figures are useful not only for societal comparisons, but for insight into financial flow in institutions and for individual dentists. A discussion of inadequate reimbursement levels could be the result.

Although the present data support general conclusions, this study has several shortcomings. Patients were treated in a clinical setting in an academic hospital, and this can create certain biases. First, dentists connected to a hospital may be more experienced than general practitioners. Therefore, the survival rates could be somewhat overstated. Second, overhead costs in an academic hospital are probably much larger than in a general practice. In addition, only patients with a marginal bone height between 8 and 25 mm were selected. All patients had a long experience with complete dentures, and they still had complaints. The population could be described as "dental cripples." Therefore, it is possible that the reported costs are somewhat higher than the costs for implants placed in routine practice settings. However, the ratio between the costs of the different treatment options can be generalized to other settings.

One of the most important shortcomings of such a comparison is the lack of data related to long-term costs. In the short term, dental implants are more expensive. However, it is likely that parts of these additional short-term costs will lead to savings in the

future because, for example, of the need for fewer rebasings and relinings. This study has shown that considerable additional investment is necessary for dental implants, as compared to traditional treatment. Costs of aftercare were considerably higher in the implant groups, so initial differences in costs during the treatment phase will most probably not be compensated for in the long run. Of course, some of the conventional prostheses, as well as overdentures supported by implants, will fail. For both treatment options, all complications during the first year were included. In all circumstances, the patients finished the first year in their own treatment group. Therefore, it was not possible to estimate costs of failure in the long term. However, between 25% and 33% of the patients in the CD group opted for implants after 1 year.[22] Furthermore, in 17% of the patients, adjustments to their prosthesis had to be made. The cost ratio in this study could actually decrease in the long run, thereby making implant-supported prostheses less economically unfavorable relative to conventional prostheses. The question remains whether the reported benefits of dental implants[1–17] justify the additional investment described here. This is the cost-effectiveness issue, about which more will be reported later.

Acknowledgments

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