Economics

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Chapter 4 Cost-effectiveness of implant-retained mandibular overdentures

Summary

The medical and the dental care sector continue to expand. Total expenditure is rising although resources are limited. Oral implantology in particular has gained a lot of ground over the last decades. Research concerning the clinical and psychosocial outcomes of treatment with dental implants has been done frequently. Dental implants tend to give better results if the clinical and psychosocial aspects are considered. However, these studies are seldom based on a randomised clinical trial. Therefore, they cannot be comparative. Furthermore, a relationship between these effects and the costs necessary to establish them has never been determined. For a more rational choice in allocating the health care budget, research into the relationship between cost and effect for this particular treatment is necessary. In this article a cost-effectiveness analysis is presented regarding overdentures on permucosal dental implants as compared with conventional treatment modalities such as preprosthetic surgery or a regular set of dentures.

Costs that treatment with dental implants result in were identified, measured and valued using the perspective of societal cost as the point of departure. Information was gathered on an individual patient level. Furthermore, the clinical and psychosocial aspects of treatment outcome were studied. As an indicator for the overall effectiveness a ratio scale for oral health was used.

The results show that the cost-effectiveness of overdentures on permucosal dental implants is definitively higher than that of the preprosthetic surgery. The choice between overdentures on permucosal implants and regular new dentures depends on assumptions for the long run. A great deal of information is lacking. Further research is needed with regard to the life expectancy of the implants, the life span of dentures, the cost of aftercare and the development of oral health for all treatment groups in the long term.

The present chapter is partly based on the following paper:
Wijk, P. van der; Bouma, J.; Oort, R.P. van; Waas, M.A.J. van; Rutten, F.F.H. (submitted). Cost-effectiveness of Implant-Retained Mandibular Overdentures.

4.1 Introduction

To date, cost-effectiveness literature in dentistry remains fairly limited. There are some studies concerning the cost-effectiveness of certain diagnostic procedures and prophylaxis[1-3]. Little is known about the cost-effectiveness of dental implants. All kinds of research has been done to establish the clinical efficacy and safety of this new dental technology. During the eighties, evidence about the efficacy of dental implants was established. However, a randomized clinical trial to compare dental implants with other conventional technologies was never reported. Moreover, an explicit investigation into the cost-effectiveness of this new technology to support the decision making process concerning admission into insurance coverage was never made. Such a comparison of different restorative technologies can be of interest for patients, clinicians, hospitals, insurance companies and the government. All of them have different reasons for gathering information about the cost and effect of these treatment modalities.

Many edentulous people are dissatisfied with their dentures. For a large group of these patients a new set of dentures will solve their problems. Sometimes surgical corrections in the form of buccal vestibuloplasty and deepening of the mouth floor can improve satisfaction. Use of dental implants may reduce problems with retention and stability and thus improve the satisfaction of patients.
The purpose of this study is to compare the cost-effectiveness of overdentures on dental implants with the cost-effectiveness of conventional strategies for people with a resorbed mandible. The conventional strategies include a new set of dentures after preprosthetic surgery or just a new set of dentures. Longitudinal data on cost and effect were gathered during one year in a randomized clinical trial. To give information on long-term cost-effectiveness, several assumptions were added based on the literature or on our own research population.

4.2 Material and methods

Patient selection

The present study was conducted at the Department of Oral and Maxillofacial Surgery and Maxillofacial Prosthodontics (University Hospital of Groningen). This randomized clinical trial included patients with serious problems with their lower dentures and a resorbed mandible, referred to the

hospital by dentists or general practitioners. Inclusion criteria were: (1) a mandibular bone height of 8-25 mm, (2) no history of dental surgery and (3) no general contra-indications. All patients were informed about different treatment modalities, possible risks and the method of treatment assignment. Written informed consent was obtained from all participating subjects. Furthermore, approval was acquired from the hospital ethical committee. Comparability between groups was ensured by balancing all groups as regards age, gender, period of edentulousness in the mandible, age of the present mandibular denture, and mandibular bone height. This method aimed at an equal distribution of patients over the treatment groups with regard to variables that may interfere with the outcome of the study[4]. Except for the number of dentures in the lower jaw no significant differences between different treatment groups were found (2-way-ANOVA; see table 1).

Table 1 Patient characteristics at baseline

Treatment	permucosal implants	preprosthetic surgery	new set of dentures
participants	(n=59)	(n=30)	(n=59)
non-participants	(n=12)	(n = 7)	(n = 3)
age	55	53	57
gender m (%)	23	37	29
v (%)	77	63	71
edentulous in lower jaw (in yrs)	22	20	23
number of mandibular dentures	2,8	2,3	2,8
mean age mandibular denture	7,2	8,2	6,9

Study design

This study is part of the ADIOS multicenter trial[5-9]. In this part of the trial, treatment with implant-retained mandibular overdentures on two permucosal implants (Brånemark or IMZ) was compared to treatment with two conventional options, one after preprosthetic surgery and one without. In the end 170 patients were randomly assigned to one of the above groups. Two groups of patients were subdivided: people with a mandibular bone height of between 16 and 25 mm and people with a mandibular bone height of 8-15 mm. The first group was assigned to anyone of the three treatment options. The latter received either permucosal dental implants or new dentures. No preprosthetic surgery was implemented in the group with low mandibular bone height because the results of surgical procedures are frequently

disappointing in cases where the mandibular bone height is less than 15 mm[7]. No significant differences were found between the higher and the lower jaw group regarding initial variables presented in table 1.
For all patients the 'Intention to treat' principle was applied. Patients who refused the allocated treatment were evaluated in the group they were originally allocated to ('Intention to Treat' principle[10]. This removes the selection bias from initial differences in motivation between treatment groups, but has as a consequence that the outcome does not reflect the treatment results fully, because these results are weakened by patients lost due to attrition (n=22). Most of the attriters were found in the invasive treatment groups (permucosal implants and preprosthetic surgery; (n=12 and n=7 respectively)).

Costs
Alongside this clinical trial, cost analyses of all the different treatment modes were performed. These cost analyses can be divided into two parts. In the first part a description is given of the actual cost, until six weeks after treatment. It also provides an estimation of societal costs during the first year. These costs are accounted for using individual cost data. Four different cost categories were used: costs of labor, equipment, technique, and overheads. Data about these cost categories was gathered during the different treatment phases: examination, fixture operation, abutment operation, prosthodontic treatment, controls, and complications until one year after treatment[11].
Non-medical individual costs -like travel costs and waiting time costs- and indirect costs (loss of labor productivity) were gathered using a questionnaire distributed among patients. All costs were converted into dollars, according to the exchange rate in 1995 (1 US$ - 1,6 DFL).

Effects
On the effect side several clinical and psychosocial criteria were used as outcome criteria. In most studies on the subject survival percentages are presented as one of the clinical end-points in the study design. These outcome measures fall short in this study. Because (a) they do not allow a comparison between implants and other technologies and (b) they do not tell us anything about the cost-effectiveness ratio of the different treatment options. The main outcome of treatment with dental implants is an improvement in oral health status. Therefore, it is important to focus on this outcome.

The subjective evaluation of the patient concerning his oral health is a major indicator for the success of treatment. Because there is no standard by which to judge in dentistry, we measured denture satisfaction using a validated self-administered 'dental complaint' questionnaire, consisting of items such as functioning, retention and aesthetics[9, 12]. These data give insight into the development of different dimensions of oral health. They cannot be used to explain cost-effectiveness in one index. Therefore, the patient's overall denture satisfaction was depicted on a ten-point rating scale (0: lowest score, 10 highest score). This outcome was taken as the end-point of this cost-effectiveness analysis.

Statistical analyses

All of the different cost components are based on individual data. A 95%-confidence interval was calculated based on the standard error of the mean. Although the costs were not normally divided, no transformation of cost functions was conducted because the skewness of the population data (caused by a few patients with high costs who wanted dental implants after their conventional treatment) was seen as a regular phenomenon.

Pretreatment comparability of the groups regarding general satisfaction with oral health was checked by analysis of variance (Tukey test). There were no significant differences. The outcome after one year was checked using this same test. A significance level of 0.05 was chosen. The 'denture complaint' questionnaire revealed six scales after using principal component factor analysis with varimax rotation [7,9]. These scales are: *functional complaints lower denture, functional complaints upper denture, functional complaints in general, physiognomy, 'neutral space', and aesthetics.* Mean scores prior to treatment did not reveal any significant deviations between the treatment groups (2-way-ANOVA).

Assumptions for main analysis of cost-effectiveness in the long run

The period of follow-up of this clinical trial was one year. To draw conclusions about cost-effectiveness in the long run, several assumptions about our research population have to be made. The assumptions in the main analysis are based on the literature and on our research population.

1- The average life span of dental implants is fifteen years for this relative old patient population. Mean life expectancy for this groups is 75 years in the Netherlands. Currently, they are on average 55 years old. The maximum life span would then be 20 years.

However, to give a conservative estimate of the cost-effectiveness ratio in the main analysis a life span of fifteen years is taken as a starting point;

2- The survival rate is 90% in the long run.
During the first year after treatment in 6% of the cases a failure of treatment was inevitable. the literature shows that loss of implants mainly happens during the first year. Survival rates reported in the literature fluctuate between 91% and 98% for a period between 0 and 9 years (table 5).

3- The life span of the set of dentures is seven years.
The patients in the population were on average edentulous for 22 years. In this period they had three different prostheses. Their last set of dentures was also approximately seven years old.

4- In this population 25% of the patients with a regular set of dentures wants implants during the first year. In the group of patients who received preprosthetic surgery this percentage is 8%. For the period of fourteen years these amounts are extrapolated to 33% and 10% respectively. The additional costs that these groups generate are corrected for in the costs of aftercare.

5- The oral health status, defined as the satisfaction of patients with their dentures expressed in a rating scale between 0 and 10, will be unaltered during this fourteen years for all different treatment groups. This assumption is the most reserved one to this extent that the expectations are that patients with a new set of dentures might face a decrease in oral health during the next years. However, this cannot be confirmed by any information from the literature.

6- Costs and effects are discounted at a 5% rate. The discount rate reflects the decision-maker's time preference for present over future outcomes. If a decision maker is indifferent between incurring $ 1 of cost today versus $ 1.10 a year from now, this implies an annual discount rate of 10%.

In the sensitivity analysis all these assumption will be loosened. Several other possibilities will be calculated. As a result of the many assumptions that had to be made to come to a conclusion about cost-effectiveness in the long run, a sensitivity analysis was performed to test the validity of conclusions made over a range of reasonable values for the assumptions made in the base line analysis. In this sensitivity analysis we calculated the threshold-values at which the conclusions about the costs-effectiveness would change.

4.3 Results

Direct medical costs

Table 2 shows the results of the cost-accounting procedure during the first year after treatment in all groups.

Table 2 Total cost of treatment, in U.S. dollars, during the first year (in 1995 dollars: 1$ = NGL 1,6)

	permucosal implants	preprosthetic surgery	complete dentures
labor	670	650	262
materials	1,803	570	575
overhead	412	392	211
hospital costs	509	2,137	63
total costs first year	**3,394**	**3,749**	**1,111**
Aftercare first year	317	59	94
non-medical and indirect costs	305	188	147
Societal costs	**4,016**	**3,996**	**1,352**
95% CI[a] total costs	3,872-4,160	3,860-4,126	1,297-1,407

[a)] Confidence Interval

The total cost of an overdenture on two permucosal implants is approximately $ 3,400. The cost of preprosthetic surgery mounts up to even more than $ 3,750[11]. Differences are due to the operation under general anesthesia and three-day admission into hospital. Although the costs of labor are somewhat less expensive than for permucosal implants, the additional hospital costs cause a major difference between these treatment modalities. Regular new dentures cost $ 1,200.

The cost of follow-up is much higher for dentures on permucosal implants ($ 317 in the first year). The cost of failures in the implant groups is included in this amount. In the conventional treatment groups, the cost of follow-up is somewhat lower: $ 59 for patients with preprosthetic surgery and $ 94 for patients with a new set of dentures. The latter is, however, only the cost of regular check-ups.

Non-medical and indirect costs

Further, we calculated non-medical (travel costs, waiting time) and indirect costs (absence from work) due to treatment. These costs are of importance when a policy decision has to be made regarding the collective financing of one of the chosen treatments. At the bottom of table 2 a survey of the non-

medical costs of all treatment options is given. Indirect costs played a minor role for this treatment and within this population.

Effects

Effects were measured on a clinical and a psychosocial basis. Clinical outcomes will not be shown, except for the survival rates of permucosal implants (table 3), because these outcome measures are not comparative between treatment with permucosal implants and the conventional treatment strategies.

Table 3 Survival percentage in the literature and in our own population

Study	year	system	survival percentage	period of follow-up
Adell et al.	1981	Brånemark	91,0%	5- 9 years
Kirsch et al.	1986	IMZ	97,2%	0- 8 years
Van Steenberghe et al.	1987	Brånemark	95,6%	0- 4 years
Bosker et al.	1989	TMI	97,8%	5-12 years
Naert et al.	1991	Brånemark	98,8%	0- 2 years
		IMZ	98,0%	0- 2 years
ADIOS[a)]	**1994**	**all**	**95,0%**	**1 year**

[a)] Academic Dutch Implant Overdenture Study

Survival percentages are comparable to those in the literature[13-17]. For 3.5% no osseointegration was reached. During the first year, in 2.5% of the patients had severe complications that led to removal of one or both implants. For the psychosocial outcomes, in this article we pay attention to the 'denture complaint' questionnaire and the subjective evaluation of the patients' oral health status and quality of life. As explained in the materials and method section, the 'dental complaints' questionnaire consisted of six constructed subscales: *functional complaints lower denture, functional complaints upper denture, functional complaints in general, physiognomy, 'neutral space' and aesthetics.* All subscales were transformed into a score of between 0 and 100, where 0 means no complaints at all and 100 is the maximum score. Figure 1 provides the results for the different treatment strategies at T1 (one year after treatment). At T0 there were no significant differences between the groups.

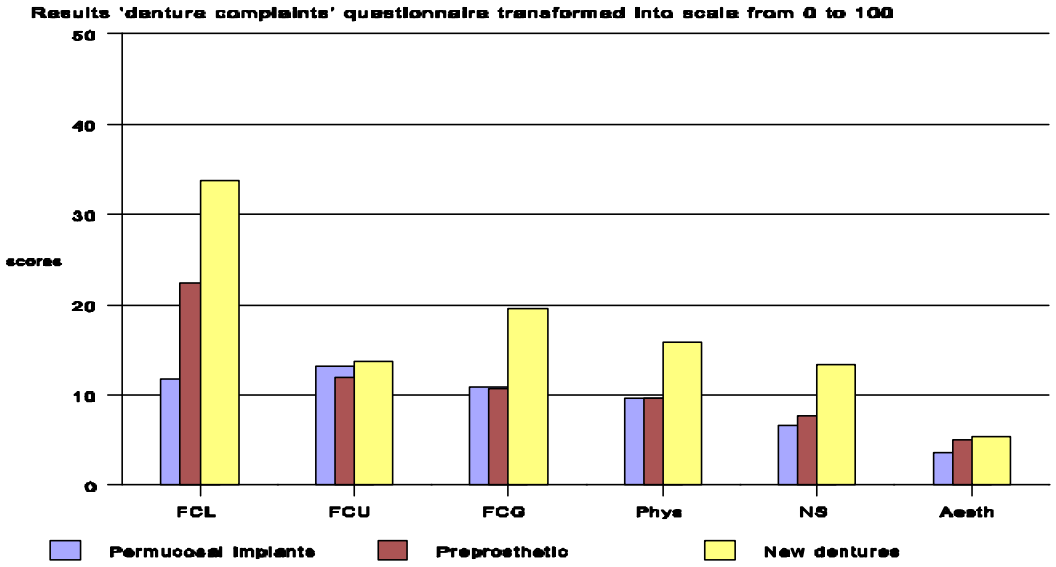

Figure 1

scale	explanation	multiple comparison[a)] [a]) Tukey-test ($p < 0.05$)
FCL	functional complaints lower denture	new dentures > preprosthetic surgery, permucosal implants preprosthetic surgery > permucosal implants
FUL	functional complaints upper denture	not significant
FCG	functional complaints in general	new dentures > preprosthetic surgery
Phys	physiognomy	not significant
NS	neutral space	new dentures > permucosal implants
Aesth	aesthetics	not significant

The permucosal implant group scored significantly fewer complaints than the conventional groups on the factor 'functional complaints lower denture'. Permucosal implants performed better on the subscales 'functional complaints in general' and 'neutral space' as compared to new dentures. Subjective ratings about the new denture were asked for both before and one year after treatment. Table 4 shows the scores on the rating scale after treatment and the average score in all treatment groups. The increment serves as a measure of the improvement in oral health as a result of treatment.

Table 4 Subjective judgment of patients concerning their oral health on a rating scale (0-10)

overall rating	permucosal implants (n=59)	preprosthetic surgery (n=30)	new dentures (n=59)
10	15.0%	3.5%	-
9	27.0%	18.0%	7.0%
8	43.0%	39.0%	23.0%
7	13.0%	18.0%	30.0%
6	2.0%	14.0%	14.0%
5	3.5%	15.5%	
4	3.5%	7.0%	
3	2.5%		
mean before	4.7 (1.5)	4.4 (1.5)	4.5 (1.6)
mean after	8.4 (1.0)	7.5 (1.4)	6.6 (1.5)
increment	3.7	3.1	2.1

There are significant differences between the implant group and the group of patients with new dentures (=0,05, Tukey test). All groups show considerable improvement in oral health.

Short-term cost-effectiveness

In table 6, under point 1, an overview is given of costs and effects during the first year, using the oral health status as a point estimate for effectiveness. As can be seen the cost per point of oral health improvement is much lower for regular new dentures than for the other alternatives.

1. For the group treated with permucosal implants costs per point of oral health are $ 1, 085 for the first year. For the group of patients treated with preprosthetic surgery this is even higher ($ 1,289 per point), while for the denture group a ratio of $ 644 per point of improvement in oral health can be found.

However, a comparison on such a short notice is not fair. The costs of the treatment with a dental implant are all centered in the first year, while returns are to be expected on the long run. For treatment with regular new dentures expectations are different: costs are to be expected in the longer run, while effects probably will decrease during the years. The main (dynamic) analysis shows that cost-effectiveness, defined as total costs in dollars per point of oral health (aggregated over 15 years) for permucosal implants is higher in the long run, based on the assumptions mentioned on page 7.

2 For the permucosal implant costs per point of oral health mounts up to $ 180. For the other alternatives this ratios are $ 223 and $ 225 respectively. Below this main case scenario, other results are given for less restricted assumptions.

To examine the robustness of our results over a range of alternative values for uncertain parameters, we performed a sensitivity analysis. In this analysis five of the six assumptions are varied one at a time (see table 5).

Table 5 Cost-effectiveness ratio's, costs per point of oral health in US Dollars. Main results and sensitivity analyses.

	permucosal implants (PI) (n=59)	preprosthetic surgery (PPS) (n=30)	complete dentures (n=59)
1. Cost-effectiveness ratio after one year	1,085	1,289	644
2. Main result	180	223	225
3a.Life span of implants 10 years	210	226	230
3b.Life span of implants 20 years	168	216	223
4a.Total disappearance of original improvement in oral health in all groups	299	365	352
4b.Decline of 0.1 point per year in all groups	225	289	373
4c.Oral health declines more quickly in group with new dentures (0.1 point per year in PI-group, 0.15 in PPS-group and 0,2 in CD-group)	225	330	549
5a.Discount rate 0%	168	194	195
5b.Discount rate 10%	207	237	243
6a.Survival percentage of implants is 80%	201	223	225
6b.Survival percentage of implants is 70%	235	223	225
7a.Percentage of people who want new implants after conventional treatment is 5% for PPS-group and 10% for CD-group	180	203	171
7b.Percentage of people who want new implants after conventional treatment is 20% for PPS-group and 50% for CD-group	180	250280	

Only assumption three concerning the life span of the dentures (7 years) is expected to be stable. This was seen as a sort of optimum term for adjustment of the prosthesis. In addition a threshold analysis was performed to show under which circumstances the outcome concerning the costs of the study would change (table 6).

Table 6 Threshold analysis concerning cost-effectiveness

Event	break-even point
Life span of implants	7.5 years
Life span of dentures	three times longer for denture-group*
Decline in oral health	two times stronger in implant-group*
Discount rate	negative*
Survival percentage of implants	< 72%
People of CD-group who want implants	< 12%

3 When the life span of implants is even longer (for example 20 years) the ratio of costs per point of oral health drops to $ 166. For preprosthetic surgery and new dentures the ratio drops slightly, because a percentage of these groups gets implants, which will survive longer. When the life span of implants is much shorter (10 years), the costs per point of oral health increases to $ 210. However, implants will still be cheaper;

4 Three different scenario's are given for assumptions on the development of oral health. In the first, the original improvement in oral health is totally disappeared in all groups, which means a much stronger decline in the implant group than in the other treatment groups. In the second, a proportional decline of 0,1 point per year for all groups is proposed. The third assumption shows the result when oral health declines more quickly in patients with new dentures. In this case the cost-effectiveness ratio of new dentures rises enormously.

5 Two different discount rates are shown. When the discount rate is 0%, decision makers are indifferent between expenditures now or in the future. In general this is not an option, because this would always lead to postponement of the project. However, this option is frequently shown in cost-effectiveness analyses, because it shows clearly what the influence of the discount rate on the final results are. Under both assumptions, implants stay the most cost-effective option. The lower the discount rate, the lower the difference between all ratio's;

6 Under (5) the results are shown when the survival percentage of the implants tends to be lower than expected. When this decreases to 70%,

regular new dentures or preprosthetic surgery will be more cost-effective;

7 Assumption six shows what happens when less people from the traditional treatment groups want implants in a later stage of their life. When 10% of the people in the denture group want implants, the cost-effectiveness ratio drops to approximately $ 175 per point of oral health;

As can be seen in the main scenario the cost-effectiveness of dental implants is the highest. When implants live longer these results even improve. This yields also for the other treatment options, because costs are postponed and oral health is supposed to be constant in the main scenario. If we vary the level of decline in oral health the position of the complete denture deteriorates. If the discount rate is kept zero, the position of the dental prosthesis is better. This is because the bulk of the costs of treatment with dental implants are made in the first year. If the survival rate of dental implants declines to 80% the costs per point of improvement in oral health rises quickly. However, at 80% the cost-effectiveness of treatment with permucosal implants is still higher than that of the other treatment options. Even so, the percentage of people who were treated with a new set of dentures but still want implants has to decline dramatically (to approximately 12%) to end up beneath the break-even point.

Treatment with dental implants will always be more expensive. However, table 6 shows the threshold analysis for the cost-effectiveness ratio: “for what changes in assumptions will the cost-effectiveness ratio shift in favor of treatment with new dentures?”. The assumptions highlighted with an asterisk, are almost impossible. Even the others are rather unlikely, although future research is necessary to shine a light on these aspects.

Cost-effectiveness

For a final judgment about the various treatment modalities three different approaches are possible. One could treat all patients with an overdenture on permucosal implants and so *maximize results* at the highest cost. One could also treat all patients with a regular set of dentures, the least expensive treatment even in the long run with inclusion of all aftercare and so obtain a *minimization of costs.* And one could approach treatment by using a method of *cost-effectiveness*, the costs per annum put out against the points of improvement in oral health measured by the ratio-scale. In the long run, the cost-effectiveness of the implants seems higher under most circumstances. If

the government has a fixed budget, the question remains: "Should we treat fewer people with better results or more people with an inferior treatment modality?"

4.4 Discussion

In the ADIOS-study the total societal costs of a specific new technology, dental implants and overdenture treatment, were estimated. In this article only the final results are shown. The resources used to treat a patient with an overdenture on a transmandibular implant can be used to treat almost seven patients with a complete new set of dentures. If we compare a regular new prosthesis with an implant-retained overdenture on permucosal implants the proportion of costs becomes more favorable, viz. 1:3. These results are comparable with a study of Jönsson and Karlsson in 1990[18]. The high costs of dental implants result not only from the treatment per se, but also from the high costs of aftercare, which is in contradiction with findings of Naert[17]. Although treatment time of aftercare is comparable for the PPS- and the CD-group, costs of material are considerably higher. Furthermore, the need for assistance by a dental hygienist to maintain a proper oral condition in the implant group accounts for additional costs. This is in accordance with the literature[19]. Oral hygiene has proved to be a prerequisite for maintaining osseointegration in implant-supported dentures[19-20]. So, two factors are related with higher aftercare costs of the dental implant group: material costs and assistance of an oral hygienist. If the treatment with new dentures requires preprosthetic surgery, this treatment is as expensive as treatment with an overdenture on permucosal implants. Costs of treatment with implants will always be higher than the other treatment options, even if the implant lasts 20 years. However, if we take into consideration the effects of treatment, measured as subjective evaluation of oral health on a ratio-scale, the cost-effectiveness of dental implants is supposedly higher than that of the other treatment modalities. In many articles on the subject the positive effects of treatment with dental implants is shown[7,21-23]. There is no gold standard for measuring these effects in one index. Therefore we used a subjective evaluation of patients themselves as a measure for outcome, based on a 'denture complaints' questionnaire. The permucosal implant group scored significantly better than the conventional treatment groups with respect to 'functional complaints lower denture'. In addition, permucosal implants did better on the factors 'functional complaints in general' and 'neutral space'. Furthermore, a subjective rating scale was filled in before and after treatment in all treatment groups. The increment served

as a measure for the improvement in oral health as a result of treatment. All groups showed considerable improvement, but the dental implant group had significantly better results than the new denture group. In short, implants are dominant to preprosthetic surgery in all different scenarios.
A statement about the comparison between new dentures and an implant-supported overdenture is more difficult to give. There is a tendency towards the implant-retained mandibular overdenture being more cost-effective. Assumptions about the life expectancy of the implants, the life span of dentures, the costs of aftercare of all treatment groups and the development of oral health, however, will determine the cost-effectiveness in the long run.

There are some shortcomings in this study that hamper generalization of the results. First, patients were treated in a clinical setting and only people with a marginal bone height between 8 and 25 millimeter were selected. Second, all patients had a very long experience with dentures and they still had complaints. The population could be described as "dental cripples". It is therefore possible that the reported costs are somewhat higher than what might have been expected from implants placed in routine practice settings. The conclusion of this study can be that treatment with dentures on two permucosal implants or treatment with a new set of dentures is more cost-effective than preprosthetic surgery. This treatment option cannot be defended from an economic point of view. Treatment with permucosal implants will almost certainly be more cost-effective than treatment with a new set of dentures, despite the fact that permucosal implants are more expensive. Further research is needed to show whether the necessary assumptions in this study have been accurate.

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