An Economic Evaluation of Implant Treatment in Edentulous Patients—Preliminary Results

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Purpose: Edentulous patients with denture problems benefit from implant treatment with overdenture prostheses. The aim of this prospective study was to investigate a method of analyzing cost effectiveness in dentistry. As an example, overdenture treatment with two or four implants was compared to the conventional complete denture (CD). ***Materials and Methods:*** In a self-selected trial, 20 patients each were treated with implant-retained overdentures (two implants, IRET), implant-supported overdentures (four implants, ISUP), or CDs (control group) in the edentulous mandible. A cost-effectiveness analysis was performed from the patient's perspective, with a time horizon of 6 months. Direct health-care costs were calculated in Swiss Francs (in 2000), and effects were defined as improvements in perceived chewing ability compared with the baseline value before treatment (measured on a VAS). Point estimates for mean incremental cost-effectiveness ratios were complemented with cost-effectiveness acceptability curves to account for uncertainties associated with costs and effects. ***Results:*** Mean incremental costs were CHF 4,329 (IRET-CD), CHF 13,360 (ISUP-CD), and CHF 9,031 (ISUP-IRET); these cost differences were all statistically significant. The mean incremental effects at 6 months were 19% (IRET-CD), 23% (ISUP-CD), and 4% (ISUP-IRET). Incremental cost-effectiveness ratios were CHF 228 (IRET-CD), CHF 581 (ISUP-CD), and CHF 2,258 (IRET-ISUP) per percentage increase in chewing ability. ***Conclusion:*** From an economic point of view, IRETs were more attractive than ISUPs. The latter were associated with a statistically significant improvement in perceived chewing ability compared to CDs, but at substantially higher costs. *Int J Prosthodont 2005;18:20–27.*

Implant treatment in the edentulous mandible is frequently indicated in patients suffering from problems with the existing complete denture (CD), such as limited chewing ability and reduced stability, discomfort, pain, and/or food getting caught under the prosthesis base. In addition, patients tend to select a soft diet that is easy to chew but has a low nutritional value.[1,2] Several studies have shown that patients benefit from implant treatment in the edentulous mandible, and that such functional limitations can be reduced or even eliminated.[1,3–6]

From a clinical perspective, distinct criteria related to jaw morphology and pathophysiologic signs and symptoms determine which treatment options are indicated and which effects can be expected from these restorations. A treatment recommendation is then made by the clinician based on the clinical criteria, the patient's major complaints, and his or her personality. Because of the elective character of implant therapy, it is necessary to inform the patient thoroughly, so that he or she is able to participate in the decision about adequate treatment. Thus, implant treatment options and

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alternative therapies should be discussed, advantages and disadvantages explained, and benefits expected from the different treatment options clarified. As the patients have to pay for the treatment, their financial means must also be considered, and the decisive factor will be the relationship between costs and benefits. To describe this relation and facilitate a comparison of different treatment modalities, a complete economic evaluation, such as the cost-effectiveness analysis (CEA), is required.[7,8]

In implant therapy, treatment costs gradually increase with the number of implants placed and depend on the materials used.[9,10] There are indications that the effects of treatment are better and functional parameters improved with increasing implant numbers. In a cross-over study comparing implant-retained overdenture prostheses (two implants) and implant-supported overdenture prostheses (cantilevered bar with four implants), patients preferred the latter because of higher stability, chewing function, and comfort as decisive variables.[11] It is, however, still not clear whether implant treatment with a removable overdenture prosthesis is more cost effective than conventional treatment with CDs, or whether two additional implants (four vs two) are associated with substantial gains in effectiveness at acceptable costs.

The aim of the present study was to investigate a method of analyzing cost effectiveness in reconstructive dentistry. As an example, implant treatment in the edentulous mandible with an implant-retained or implant-supported removable overdenture prosthesis was compared to CDs.

Materials and Methods

Sixty edentulous patients who visited the Clinic for Restorative Dentistry, University of Basel, Switzerland, between January 1999 and December 2001 and required treatment in the edentulous mandible with removable prostheses with or without implants were included in the study. Patients were informed about the study outline and gave their informed consent.

Pretreatment Questionnaire

Before the start of the study, patients were asked to complete a questionnaire ("Patient Satisfaction Related to Prosthetic Restoration"). This comprised data related to the history of tooth loss, the patients' assessment of their present CDs in the mandible and maxilla, and their oral health and how it affected them psychologically. The parameters chosen were overall satisfaction, perception of prosthesis retention and stability, perceived chewing ability, difficulties with food particles getting caught under the dentures, pain related to the dentures, esthetics, and appearance. To clarify the meaning of the term "chewing ability," explanatory questions were added: "Can you eat properly with the restoration?" and "Which food can't you chew?" The psychologic impact of oral health was assessed with the following questions: "Is your self-confidence affected?" and/or "Do you feel insecure with your teeth/the restoration?" and "Do you perceive the restoration as a foreign body?"

The questionnaire was carefully explained to the patient, who was asked to place a mark on a visual analogue scale (VAS) at a point corresponding to his or her level of satisfaction or discontent with each factor. The left end of the horizontal beam represented 0%, the negative limit (worst state), and that on the right corresponded to 100%, the positive limit (best state). The percentage given by the location of the cross (X) at the 10-cm horizontal beam was then related to the corresponding values between 0 and 100 using a gauge with scales from 0 to 100 mm. The reliability of the questionnaire was evaluated in a pilot study with five additional edentulous patients also requiring treatment in the edentulous mandible. They repeated the questions after 1 week, with an intraclass correlation coefficient between .9963 and .9999 for the different parameters. All patients were asked to indicate the main reasons for seeking treatment in the mandible.

Study Outline and Treatment Procedure

The study was designed so that patients selected the treatment that, in their opinions, suited them best (self-selected trial[12]). Before deciding on the treatment, patients were informed about the established treatment options in the edentulous mandible, ie, a conventional CD, overdenture prosthesis with two implants and ball abutments (implant-retained overdenture [IRET]), or overdenture prosthesis supported by a bar with four implants (implant-supported overdenture [ISUP]). The advantages and disadvantages of the different treatment options, possible risks, and methods employed were discussed with the patient, and an individual treatment recommendation was given by the specialist, primarily based on the anatomic situation, the patient's major concerns, and the estimated costs (covered by the patients themselves). The CEA was therefore conducted from the perspective of the patient.

Initial direct medical costs were estimated according to the official national dental tariff structure, which did not change during the study period (1999 to 2002). These costs included the implant material, surgical and prosthodontic treatment, as well as laboratory fees. A new CD in the maxilla and a metal reinforcement of any mandibular overdenture reconstruction

were also included in these calculations. Costs were estimated as a maximum of CHF 4,000 for the conventional CD, CHF 8,000 for an overdenture with two implants and ball abutments, and CHF 15,000 for an overdenture with four implants and a cantilevered bar. Depending on patients' individual pretreatment needs (eg, adaptation of the existing denture), deviations from these cost estimates were calculated as necessary. Patients were informed about the option to have the prosthetic treatment performed within the undergraduate program at a reduced fee but with a longer treatment time than in the postgraduate clinic.

Patients who fulfilled the following criteria were included in the study: *(1)* they had worn CDs in the maxilla and mandible for at least 3 months; *(2)* they had decided to have overdenture treatment with two or four implants or CD treatment in the mandible; *(3)* they agreed to conventional CD treatment in the maxilla; and *(4)* they were willing to conduct any maintenance requirements at the university clinic for at least 12 months following treatment completion. No exclusion criteria related to age, smoking status, and/or medication were applied. Twenty patients were included in group 1 (overdenture treatment with two implants, IRET), 20 in group 2 (overdenture treatment with a bar and four implants, ISUP), and 20 in group 3 (control group with CDs). Patients who selected treatment with fixed implant prostheses in the mandible and/or requested implant treatment in the maxilla were not included in this study.

In group 1, two implants were placed ad modum Brånemark (Brånemark system, Nobel Biocare) in the left and right mandibular first premolar or canine areas. Overdenture prostheses were fabricated and retained at two ball abutments (IRET). In group 2, four implants were placed in the interforaminal area, and an ISUP was fabricated, resting on a bar with posterior extensions. In both implant groups, submerged implant healing for 4 months was permitted. In group 3, patients were provided with a CD in the mandible. Each subject in groups 1, 2, and 3 received a maxillary CD with 12 functional units. The actual direct medical costs were calculated following treatment completion and expressed in Swiss Francs (CHF).

Follow-up Questionnaire

Six months following completion of the restorative treatment, patients were recalled and given the same VAS questionnaire to evaluate their satisfaction with the new restoration and the psychologic impact of the treatment with IRETs, ISUPs, or conventional CDs in the mandible. The difference between chewing ability after 6 months and the baseline value before treatment was used as an outcome measure in the CEA. The difference in the VAS percentages was calculated and was negative (worse outcome), 0% (no improvement), or positive (improvement after treatment). The time horizon of the CEA was 6 months, and no discounting of costs and effects was applied. The results of the additional parameters evaluated in the questionnaire will be presented in a separate article.

Statistical Analysis

Mean values and standard deviations were calculated for costs and effects in each group. In addition, a bivariate distribution of mean costs and effects was generated with the bootstrap method (using 5,000 samples).[13] For comparison of the implant treatment (IRET or ISUP) with conventional CDs and comparison of treatment with two versus four implants (IRET vs ISUP), incremental costs were divided by incremental effects and expressed as incremental cost-effectiveness ratios (ie, the additional resources needed for an additional unit of effectiveness). The bootstrap method was also applied to estimate the bivariate distribution of mean incremental costs and effects for the strategies to be compared. These bivariate distributions were then used to generate the corresponding cost-effectiveness acceptability curves, which graphically describe the probability that the intervention is cost effective for all possible ceiling ratios. The ceiling ratio represents the incremental cost-effectiveness ratio above which an intervention is deemed cost ineffective and is often interpreted as the decision maker's (the patient in the current study) "maximum willingness to pay" per incremental gain in effectiveness.[13] All statistical analyses were performed using S-Plus 6.1 Professional (Insightful).

Results

Patients in group 1 had a mean age of 71.4 ± 9.7 years (range 55 to 84 years). In group 2, the mean age was 69 ± 9.7 years (range 44 to 81 years), and in the control group, patients were 73.6 ± 9.4 years old on average (range 57 to 98 years). The study population comprised 39 women and 21 men. The implant groups (IRET and ISUP) and control group (CD) were similar in terms of age, sex distribution, age of tooth loss, and duration of edentulism in the maxilla. Differences among groups were observed in the duration of edentulism in the mandible. Thus, patients in group 2 were seeking implant treatment after a shorter period, ie, after 7.1 ± 10.4 years of edentulism, compared to IRET (17.3 ± 17.8 years) and CD (23.3 ± 15.8 years) patients. Chewing ability and prosthesis stability were mentioned by 60.4% of the subjects as main reasons for seeking treatment.

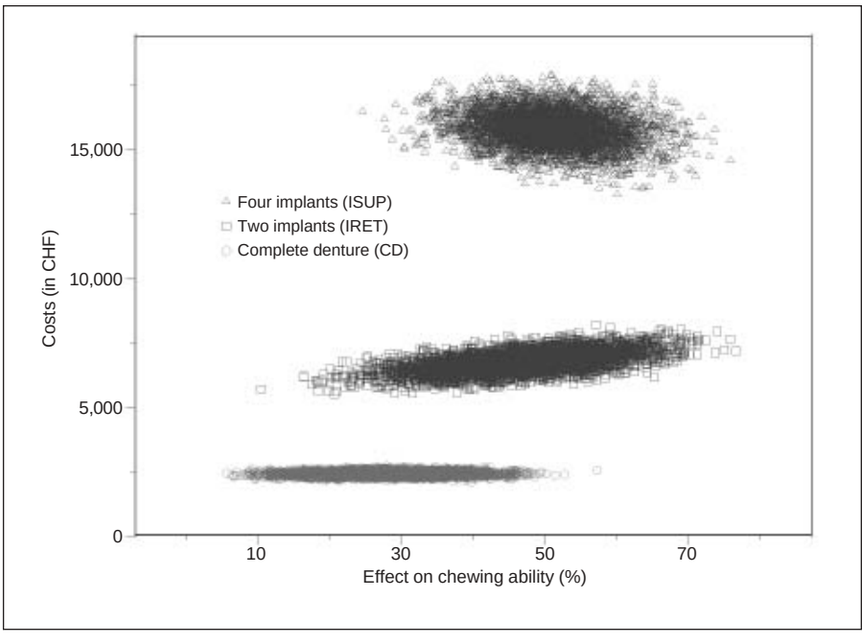

Fig 1 Bivariate distribution of the total costs and effects of the three treatment options in the edentulous mandible.

Both parameters were closely related to overall satisfaction (Spearman correlation rho 0.81).

During healing following implant placement, one implant was lost and successfully replaced at once (group 2). No additional implant failures were observed during the study period.

Total Costs and Effects

Direct total costs were on average CHF 6,774 ± 1,720 for group 1 (IRET), CHF 15,805 ± 3,064 for group 2 (ISUP), and CHF 2,445 ± 385 for the control group (CD). Treatment in the undergraduate clinic was selected by 15 patients in group 1, 10 subjects in group 2, and 17 patients in group 3. The treatment effect (improvement in perceived chewing ability) was 46.8% ± 40.9% for group 1, 51.0% ± 32.2% for group 2, and 28.1% ± 32.1% for group 3. The bivariate distributions of the mean total costs and effects for the three groups are shown in Fig 1. For CD, the plot of bootstrap replicates formed a flat horizontal cloud, indicating no correlation between costs and effects ($r = 0.03$). For group 1, there was an upward kink in the distribution of mean total costs and effects, indicating a positive correlation between costs and effects ($r = 0.56$). The downward kink in the bivariate distribution of mean total costs and effects for group 2 indicated a negative correlation ($r = -0.21$), with higher costs being associated with worse outcomes (Fig 1).

Incremental Costs and Effects

Mean incremental costs were CHF 4,329 (IRET-CD), CHF 13,360 (ISUP-CD), and CHF 9,031 (ISUP-IRET). The differences in costs between IRET and CD, ISUP and CD, and ISUP and IRET were statistically significant ($P < .001$). The mean incremental effects at 6 months were 19% (IRET-CD; $P = .056$), 23% (ISUP-CD; $P = .025$), and 4% (ISUP-IRET; $P = .366$). The incremental cost-effectiveness ratios were CHF 228 (IRET-CD), CHF 581 (ISUP-CD), and CHF 2,258 (IRET-ISUP) per percentage gain in chewing ability. The bivariate joint distributions of incremental costs and effects are shown on the cost-effectiveness planes in Fig 2. Comparison of implant treatment and conventional therapy showed that the majority of the joint distributions fell into the upper right quadrant of the cost-effectiveness plane (northeast [NE]; Fig 2a). Higher costs for implant treatment were therefore associated with greater benefits than the CDs. Outcome differences were statistically significant for ISUP versus CD ($P = .025$), and there was a trend for the comparison of IRET versus CD ($P = .056$; Fig 2a). The proportion of the 5,000 bootstrap replicates falling in the northwestern (NW) quadrant reflected the one-sided P value for the effect difference. Comparing the two implant therapies (ISUP vs IRET), there was no statistically significant difference in the treatment effect ($P = .366$; Fig 2b).

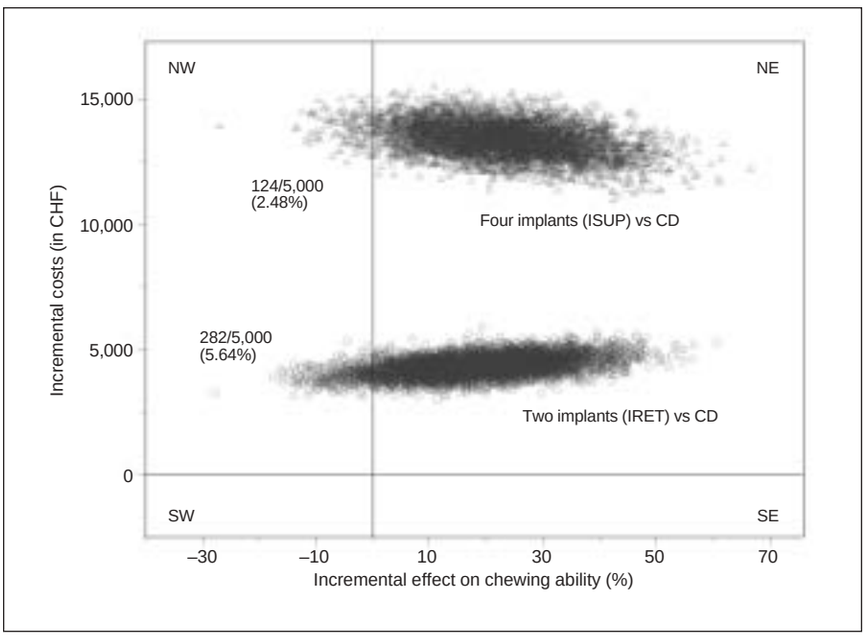

Fig 2a Bivariate distribution of mean incremental costs and effects of IRET and ISUP versus CD on cost-effectiveness plane.

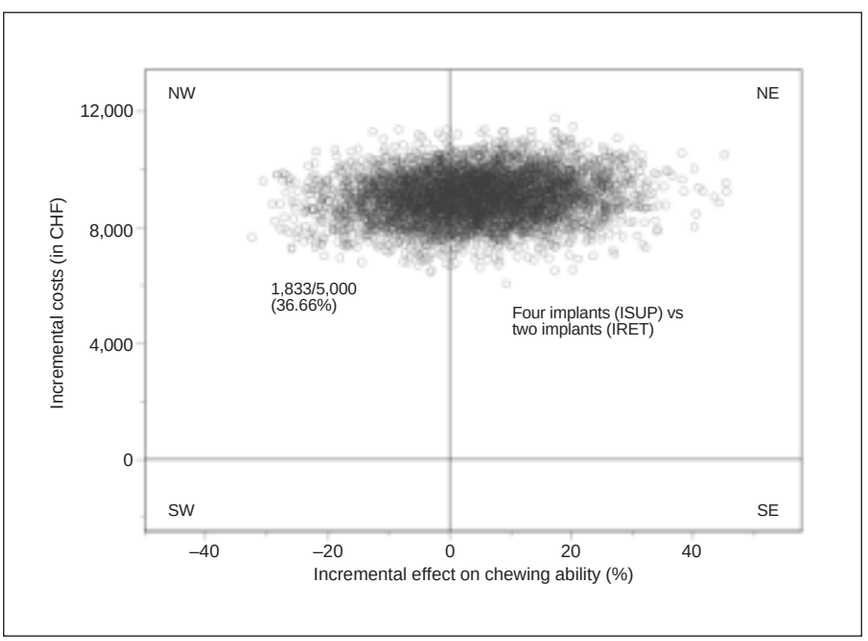

Fig 2b Bivariate distribution of mean incremental costs and effects of ISUP versus IRET on cost-effectiveness plane.

Acceptability Curves

The cost-effectiveness acceptability curve of IRET versus CD was steep, indicating that the implant intervention is already likely to be cost effective at low values of the ceiling ratio (Fig 3a). The cost effectiveness of the intervention did not, however, reach statistical significance, ie, the cost-effectiveness acceptability curve did not cross the horizontal line at 0.95. For the comparison of group 2 (ISUP) with group 3 (CD), the initial part of the acceptability curve showed a more gentle slope (Fig 3a). The cost effectiveness of ISUP versus CD reached statistical significance at a ceiling ratio of CHF 3,503 per percentage gain in chewing ability, ie, where the curve crossed the horizontal line at 0.95. The assessment of two or four implants compared with CDs indicated that at lower levels of the ceiling ratio, the probability that the intervention is cost effective was higher with IRET versus CD than with ISUP versus CD. The intersection of the two curves corresponded to a

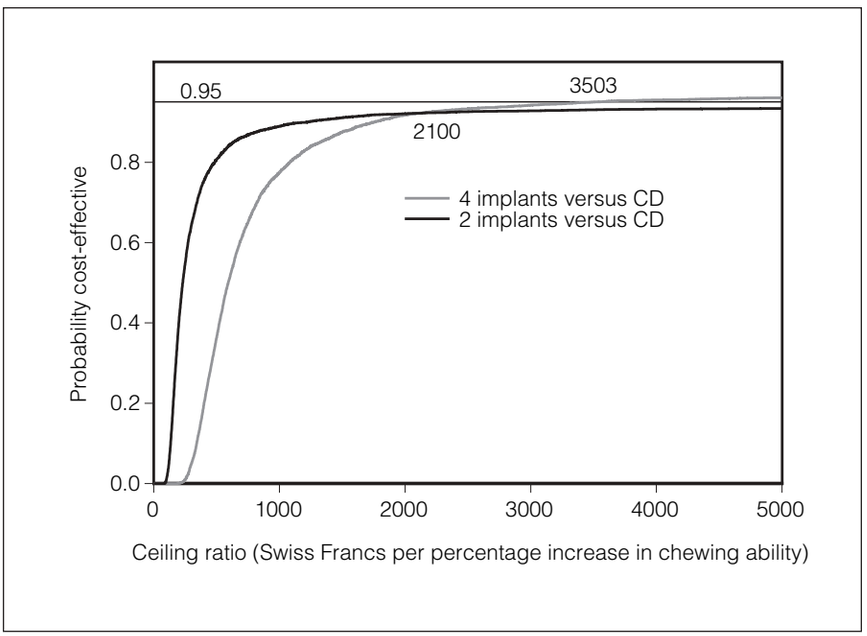

Fig 3a Acceptability curves for IRET and ISUP versus CD.

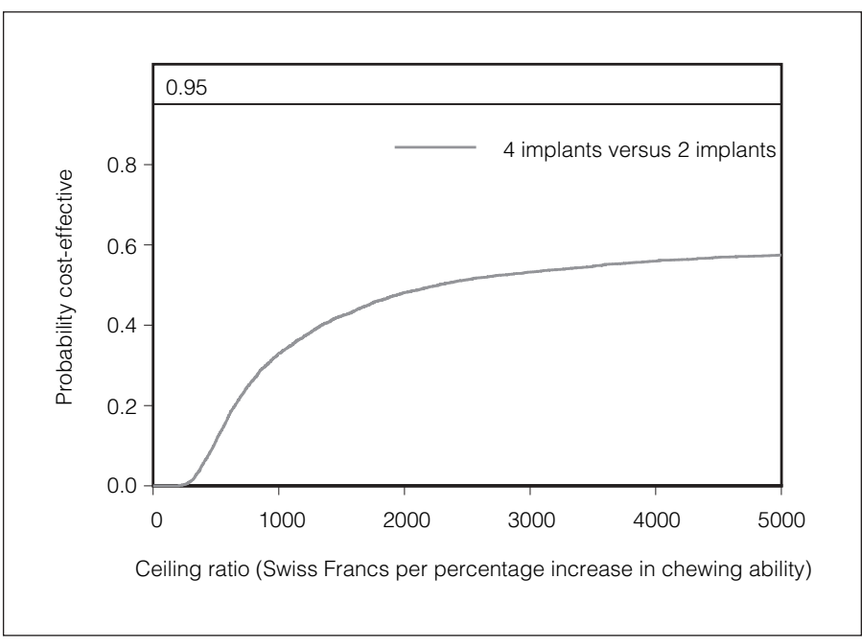

Fig 3b Acceptability curve for ISUP versus IRET.

ceiling ratio of CHF 2,100 per unit of effect. Thus, for ceiling ratios above CHF 2,100, ISUP is the preferred treatment because the cost-effectiveness acceptability curve of ISUP versus CD lay above that for IRET versus CD (Fig 3a).

Comparing groups 2 and 1 resulted in a flat curve, which indicated that even at high levels of the ceiling ratio, ISUP versus IRET did become cost effective with a relatively small probability of approximately 60% (Fig 3b). This is due to the fact that ISUP was dominated by IRET in 37% of the bootstrap replicates, as shown in Fig 2b.

Discussion

The findings of the present study confirm that implant treatment requires higher initial costs, almost 3 times higher for two implants and 6 times higher for four implants than for conventional treatment with CDs. These higher costs can be justified, as the benefits are greater.

Patients who had undergone the implant treatment perceived greater improvements in chewing ability than those who had the conventional treatment.

The CEA revealed that IRET was the more cost-effective implant treatment option, with an incremental cost-effectiveness ratio of CHF 228 (IRET-CD), compared to CHF 581 (ISUP-CD) and CHF 2,258 (IRET-ISUP) per percentage increase in chewing ability. Given a high willingness to pay per unit of effect, ISUP was significantly more cost effective than CD ($P < .050$), whereas the cost effectiveness of IRET compared to CD almost reached statistical significance. ISUP was, however, dominated by IRET in 37% of the samples, which indicates that the effect difference was not statistically significant, whereas the costs of ISUP were significantly higher. ISUP compared to IRET therefore cannot be considered either effective or cost effective if chewing ability is used as the outcome measure.

In the present study, several factors related to patients' satisfaction with their oral health and psychologic impairment were assessed by recording patients' perceptions before and after treatment. Improvement in perceived chewing ability was chosen as the representative outcome parameter because it showed the highest responsiveness in all three groups. In addition, chewing ability and prosthesis stability were most frequently mentioned as main reasons for seeking treatment.

In the control group, the treatment effects were associated with relatively stable costs. For IRETs, there was a positive correlation between larger effects and higher costs, whereas with ISUPs, higher costs were possibly related to smaller effects. This negative correlation in ISUP may be due to the population characteristics, with a complex morphologic situation being responsible for the smaller amount of improvement. Additionally, it can be assumed that patients with ISUPs already had greater expectations about the treatment outcomes, as they had agreed to pay considerably more. They required and requested treatment with implants after a shorter period of edentulism than those who decided on IRETs or CDs. This observation indicates that, in patients selecting ISUPs, functional and/or psychologic impairment was possibly more conspicuous. This assumption was not, however, confirmed by any group differences in the parameters assessed by VAS before treatment. Although the majority of restorative procedures were performed in the undergraduate clinic, no variation in treatment quality was expected because of the meticulous observation of and assistance with the dental work by postgraduates and/or specialists. The time costs, however, were usually greater for those patients who selected treatment in the undergraduate program. This aspect still needs to be investigated, and the maintenance efforts and costs in the different treatment groups compared after a longer observation time. It must be emphasized that these aspects—treatment in the under- or postgraduate clinic and the self-selection of the therapy (preference trial), with the patient as a payer—may introduce some bias in the outcome and therefore limit the conclusions that can be drawn from the current results.

For a complete economic evaluation of health care interventions, the methods of CEA, cost-utility analysis (CUA), or cost-benefit analysis (CBA) are usually used.[7,8,14,15] In the current study, a CEA was conducted to compare both the costs and effects of implant treatment with those of conventional CDs in the mandible. For the comparison of removable (IRET) and fixed (IFIX) implant prostheses, Attard et al[16] used a cost-minimization analysis (CMA) in which only costs are compared, assuming an equal treatment outcome between the strategies. This method was applied because the effects did not show a statistically significant difference in the first place. The appropriateness of CMA, however, has been questioned.[17] Attard et al[16] observe that both the initial and maintenance costs (over 9 years) were 3 times higher for IFIX than for IRET. Direct and/or indirect costs (loss in productivity) have been the subject of several studies investigating different implant treatment modalities in the edentulous mandible.[9,18–20] Lewis[9] reports that direct costs (including initial and maintenance costs) for an IRET were twice as high as those of conventional CDs, whereas costs of an implant-supported fixed partial denture (IFIX) were 4 times as high as those of CDs. Takanashi et al[18] compared the direct and indirect costs of IRETs and CDs during scheduled and unscheduled visits over a 1-year maintenance period. In accordance with the present study, the initial direct costs of implant treatment were almost 3 times higher than those for the conventional treatment. The difference in indirect costs was, however, small between the two treatment options.[18] Jönsson and Karlsson[19] compared the direct and indirect costs of implant restorations (IFIX) and CDs in the edentulous mandible during a 5-year period after implant placement. The direct costs for IFIXs were more than 6 times higher than those for CDs. In the implant treatment, the indirect costs amounted to 16% of the direct costs, whereas traveling costs (direct nonmedical costs) made up only 1% of the direct costs.[19] Palmqvist et al[20] used the same number of implants for fixed and removable prostheses and compared clinical and laboratory working hours, laboratory costs, and materials used for these treatments. Laboratory efforts were greater with IFIXs than with ISUPs, but this difference was compensated for by ISUPs requiring more clinical working hours.[20]

When comparing these data, it must be considered that the financial variables may well be greatly

influenced by local factors, such as the tariff structure, cost of living, and mean income. The documented proportions of the direct initial costs in the studies referred to[9,16,18] are, however, in agreement with the results of the current investigation.

The findings of the current CEA indicate that, from an economic point of view, IRETs are more attractive than ISUPs. The latter are associated with a statistically significant improvement in perceived chewing ability compared to CDs, but at substantially higher costs.

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Literature Abstract

Cemented versus screw-retained implant-supported single-tooth crowns: A 4-year prospective clinical study

The choice of cemented vs screw-retained prostheses for prosthetic reconstruction involving endosseous implants seems to be mainly based on the clinician's preference. The aim of this study was to compare cemented and screw-retained, implant-supported, single-tooth crowns with respect to peri-implant marginal bone levels, peri-implant soft tissue parameters, and prosthetic complications. In 12 patients, one edentulous site was randomly chosen to receive a cemented implant-supported single-tooth crown; and in the contralateral edentulous site, a screw-retained, implant-supported, single-tooth crown would be placed. All definitive restorations were cemented with temporary cement (Temp Bond NE; Kerr Italia, Scafati). For the screw-retained crowns, the gold UCLA-type abutments were used. After prosthetic treatment, the patients were checked every three months in the first year and every six months in subsequent years. Statistical analysis was performed using paired Student *t* test. No prosthetic complication was reported. Clinical evaluation of the peri-implant mucosa using periodontal indices revealed similar satisfactory results for the implant-mucosa interfaces. The mean marginal bone resorption at four years after implant placement was 0.8 mm with a range between 0.5 and 1.2 mm for both types of restoration. The statistical analysis revealed no significant difference between the two groups ($P < .001$). This study concluded there was no evidence that one method of retention was clinically or biologically superior to the other. Therefore, the choice of cementation versus screw retention should be primarily related to the clinician's preference.

Vigolo P, Givani A, Majzoub Z, Cordioli G. *Int J Oral Maxillofac Implants* 2004;19:260–265. **Reference:** 39.

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