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Economic evaluation of single-tooth replacement using fixed dental prosthesis or implant-supported single crowns

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Abstract

Objectives: Dentists and patients are frequently confronted by a difficult treatment decision: should a missing tooth be replaced with a fixed dental prosthesis (FDP) or an implant-supported single crown (ISC)?

Material and methods: 47 patients with one singular missing tooth and 6 patients with two singular missing teeth in non-adjacent positions were included in this study. 29 tooth gaps were closed with FDPs and thirty with ISCs. Material costs, treatment hours and number of visits were recorded and compared for the two treatment groups.

Results: Due to surgery, the total number of visits was higher for the ISC than for the FDP group (7.5±2.8 vs. 6.2±3.6; p=0.03), but the actual chairside time was the same (5.3±1.8 hours vs. 5.0±2.5 hours; p=0.22). Pretreatment costs were significantly lower for the ISC group CHF (278.6±306.2 vs. 847.8±722.4 p=0.001), as were the costs for the dental technicians CHF (1211.6±395.2 vs. 1498.2±492.6; p<0.001). Except for the costs of managing complications, which were very low anyway compared to other costs, ISC consistently showed lower values than FDP for treatment costs and material costs. The total average cost of treatment amounted to CHF (4380.10±64.80) for the ISC group and CHF (4503.50±1124.30) for the FDP group.

Conclusions: Placement of implant-supported single crowns was more cost effective than placement of a fixed dental prosthesis for the replacement of single missing teeth, with implant reconstruction demonstrating a more favorable cost-benefit ratio. In clinical situations involving teeth with no or minor restorations and/or sufficient bone for standard placement, reconstruction with implants is to be recommended.

Introduction

Single-tooth replacement can be achieved through the use of a conventional fixed dental prosthesis (FDP) or a single implant-supported crown (ISC). For many years FDPs were the method of choice; however, the high survival rates of osseointegrated dental implants have led to new treatment options. Both approaches aim for long-term success and the best esthetic and functional outcomes. The choice of treatment is dependent on many factors, such as intra- and intermaxillary relationships, soft tissue characteristics, patient facial esthetics, as well as the size, shape and color of the teeth. Additional factors influencing the choice of treatment are the condition of the adjacent teeth, the supporting teeth and the antagonists. The practitioner's experience and level of expertise and the patient's financial situation are further factors of importance (Brägger et al., 2005; Jivraj et al., 2008; Antonarakis et al., 2014).

A systematic review of the most recent studies on the outcomes, benefits, and disadvantages of tooth replacement by implant-supported crowns compared to fixed dental prostheses on teeth revealed higher success rates and superior long-term survival for ISCs compared to FDPs (Torabinejad et al., 2007; Nickenig et al., 2008). A recent 10 year study from the United States showed that ISCs had an average survival rate 10.4% higher than the survival rate of FDPs (Kim et al., 2014). For the replacement of multiple teeth, dental implants (fixed or removable prosthesis) were associated with higher initial costs but increased improvements in oral health-related quality of life compared to other treatment options (Vogel et al., 2013). Investigation of factors affecting various prosthetic treatment modalities revealed that pain and dental phobia were important factors in choosing the prosthesis type, and that the main reason for choosing dental implants was to leave the adjacent teeth intact and not to expose them to the risks associated with FDP on teeth (Al-Shammari et al., 2005; Christensen, G. J. 2008; Al-Quran et al., 2011).

In many cases, however, the cost of the treatment is considered a major determinant of the final treatment decision (Al-Quran et al., 2011). Contradicting opinions on the costs associated with the two treatment options have been reported. For example, when replacing a missing maxillary lateral incisor, ISC was found to be a more cost-effective treatment modality than FDP (Antonarakis et al., 2014). In particular, replacement of a single missing tooth by ISCs was found to cost ~570 USD less (~555 CHF less) using ISCs compared to FDPs (Brägger et al., 2005). On the other hand, a 10-year study from the US showed that ISCs cost approximately 300 USD more (~290 CHF more) than FDPs (Kim et al., 2014).

Analysis of these studies revealed that, for single-tooth replacement, dental implants were generally either cost-saving or more cost-effective in comparison with tooth replacement using traditional fixed dental prosthesis (Vogel et al., 2013). The consensus in these studies was that dental implants were associated with higher initial costs in comparison to fixed partial dentures, but that over the long term, dental implants represented a cost-effective treatment option.

Experts attending the 2015 European Association for Osseointegration (EAO) consensus conference agreed that missing tooth replacement with single implant-supported crowns was more cost-effective and provided better outcomes in terms of survival rates compared to fixed or removable partial dentures (Beikler & Flemmig, 2015). In another economic evaluation, however, it was found that implant-supported crowns cost more than fixed dental prosthesis (Beikler & Flemmig, 2015). This expert group concluded that in order to better assess the efficiency of implant-supported prosthesis in various clinical situations, more economic evaluations following well-established methodologies in health economics were needed.

The aim of this study was to evaluate and compare the cost-effectiveness of two different treatment alternatives (ISC and FDP) for replacement of a single missing tooth in a private dental practice. The results of this study may facilitate decision-making for single-tooth replacement.

Materials and methods

Patients

All 53 patients who required single-tooth replacement in one private practice were included in this study. Six out of 53 patients received two consecutive treatments for single-tooth replacements so that, in summary, 59 single-tooth replacements were analyzed. The general inclusion criteria consisted of having received one or more ISCs or FDPs from the same private practice between May 1995 and November 2005.

Treatment

Patients who had received a single crown on an implant of the Nobel Biocare Replace ™ Implant system (Nobel Biocare Holding AG, Zürich, Switzerland) were allocated to group A. Patients who had received a conventional tooth-supported three-unit fixed dental prosthesis were allocated to group B.

The positions of all single-tooth replacements are summarized in Table 1. None of the patients presented with a free-end situation, which excluded also extension bridges. On the other hand, Maryland Bridges were not favored due to challenging occlusion forces.

Table 1. Positions of single-tooth restorations according to the Fédération Dentaire International (FDI)

Group A, ISC

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
		4 3	2 1	4	2	2	2	1	2	1	2	1	2 1		
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38

Group B, FDP

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
		2 1	1 2	1 1		3	1		1	1 1	1	4 2	3 4		
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38

The choice of treatment was based on the preferences of the patients and the dentist, but was also based on common indications for FDPs, such as bone availability or caries on adjacent teeth. All patients had received comprehensive treatment for their periodontal, endodontic, cariologic, esthetic and functional needs. The pretreatments performed in the two groups included apicoectomy, tooth extraction, root canal treatment, crown build-ups with or without core and post, removal of defective reconstructions, fabrication of temporaries, and ridge augmentation using a bovine-derived bone graft (Bio-Oss, Geistlich Biomaterials, Wolhusen, Switzerland) as well as a resorbable membrane (Bio-Gide, Geistlich Biomaterials, Wolhusen, Switzerland). The pretreatment therapies performed in the two groups are listed in Table 2.

Table 2. List of pretreatment therapies in group A (14 pretreatment therapies) and group B (35 pretreatment therapies)

Pretreatment	**A) Implant-supported single crown**	**B) Fixed dental prosthesis**
	n	**n**
Already edentulous	3	0
Apicoectomy	3	0
Bone grafting	5	1
Composite core build-up	0	2
Post and core	0	15
Removal of old FDP	0	2
Root canal treatment	0	15
Separation of crowns	3	0

For fixed dental prosthesis abutment teeth were prepared using different diamonds and a red counterangle handpiece with ample cooling. The abutment teeth of group B were covered and protected using temporary crowns, which were cemented using Tempbond (Kerr-Hawe SA, Bioggio, Switzerland). Porcelain fused to metal fixed dental prosthesis was fabricated in all cases.

All patients were asked to immediately report any complications or complaints. The patients were recalled in approximately six-month intervals, with a dental hygienist performing periodontal reevaluation and periodontal recall.

Implant surgery consisted of a crestal incision extending to the sulci of the adjacent teeth. Buccal and lingual full thickness flaps were raised to allow inspection of the available bone dimension and volume. The diameter and the length were chosen based on the anatomical and radiographic situation and placed according to the manufacturer's recommendations.

The implants were placed in either a transmucosal or a semisubmerged position followed by torqueing of the healing caps and suturing. Patients were requested to rinse twice daily with 0.02% Chlorhexidine solution for two weeks. After an average of 4.5 months of healing, impressions were taken at the implant level. The technician was instructed to choose the most suitable abutment and to produce a single crown made of porcelain fused to metal. All of these crowns were fabricated in the same dental laboratory by the same technician and were cemented using resin-reinforced glasionomer cement GC Fuji PLUS (GC Austria GmbH, Flums, Switzerland).

Patient records

The following parameters were recorded based on the patients' charts and appointment schedules:

- Number of visits and time (in hours) needed for pretreatment of edentulous space and/or the teeth adjacent to the edentulous space
- Number of visits and time (in hours) needed for the actual reconstruction, tooth preparation, implant placement, impression taking, try-ins of FDPs or single crowns
- Number of visits and time (in hours) needed for management of either biological or technical failures as well as complications during the maintenance phase

Costs

Only direct costs were taken into consideration in the present analysis. Indirect costs, such as staff salaries, overhead costs, patient travel costs, and lost earnings, were not included. For the direct treatment costs, to ensure proper estimation, both dental clinical and laboratory costs were considered. For the FDP options, anesthesia for abutment tooth preparation as well as temporary restorations was included in the dental clinical costs.

The costs of the two different treatment modalities were calculated based on the national fee scheme in Switzerland, provided by the Swiss Dental Association, using a point scheme used by health insurances for reimbursement purposes, which has not changed since 1994.

The costs of the dentist's treatment time, any biomaterials applied, implant components used, as well as the fee for the laboratory technician (based on the reimbursement fee used by Swiss health insurances for technicians' fees) were separately listed for the pretreatment phase, for the actual reconstructive phase, as well as for the maintenance phase. Dental hygiene fees were not included.

Statistics

Descriptive statistics were computed using medians and standard deviations for all variables. Comparisons of two means were performed with Wilcoxon-Mann-Whitney tests due to the small sample size. No correction for multiple testing was applied due to the explorative nature of this study. The level of significance was set at 0.05.

All calculations were done with R, version 3.2.2 (The R Project for Statistical Computing, Vienna, Austria) using the additional package "exact Rank Tests".

Results

Sample

The sample consisted of n=59 single-tooth replacements in 53 patients which were performed between May 1995 and November 2005 by the same private dentist. Among the single-tooth replacements, n_1=30 were treated with an implant-supported single crown (ISC) and n_2=29 with a fixed dental prosthesis (FDP).

Figure 1 Example of a fixed dental prosthesis for replacing tooth number 36

Figure 2 Example of an implant-supported single crown for replacing tooth number 41

Of the 53 patients, 33 were female and 20 male. In group A, ISC, the mean age was 51.69 years (range: 23.10–80.10); in group B, FDP, the mean age was 52.61 (range: 19.80–75.20). The factors determining the treatment decision are summarized in Table 3.

Table 3. Factors determing the treatment decision

Reason for ISC	**n (%)**	**Reason for FDP**	**n (%)**
Bone resorption	14 (46.7%)	Bone resorption	1 (3.4%)
Endodontic complications	1 (3.3%)	Endodontic complications	3 (10.4%)
Absence of or small fillings in adjacent teeth	13 (43.3%)	Failure of previous FDP	4 (13.8%)
Absence of tooth distal to respective region	2 (6.7%)	Periodontal abscess	1 (3.4%)
		Edentulism	4 (13.8%)
		Extraction	4 (13.8%)
		Root fracture	1 (3.4%)
		Unknown	11 (38%)

The reasons for choosing FDP treatment instead of ISC treatment were indicated in Table 4.

Table 4. Reasons for FDP instead of ISC treatment

Reason for FDP or ISC treatment	**n (%)**
Patient preference	8 (27.6%)
Pre-existing FDP in this region	4 (13.8%)
Previous FDP in another region	2 (6.9%)
Large fillings in adjacent tooth	2 (6.9%)
Insufficient space for implant	2 (6.9%)
Unknown	11 (37.9%)

Follow-up time

The average follow-up time was 27.60 months (±17.15) in the ISC group and 85.18 months (±34.17) in the FDP group. The follow-up time was significantly shorter for ISC than for FDP ($p<0.0001$).

Number and duration of visits

In Table 5, the numbers of visits needed for the preparation of the site, for the actual replacement of the missing tooth and for taking care of biological and technical complications during the maintenance phases as well as the total number of visits were listed. While fewer visits were needed in the implant group during the pretreatment phase, more appointments were scheduled during the surgical phase and the implant healing period. The total number of visits was statistically insignificantly higher in the ISC group (Figure3)

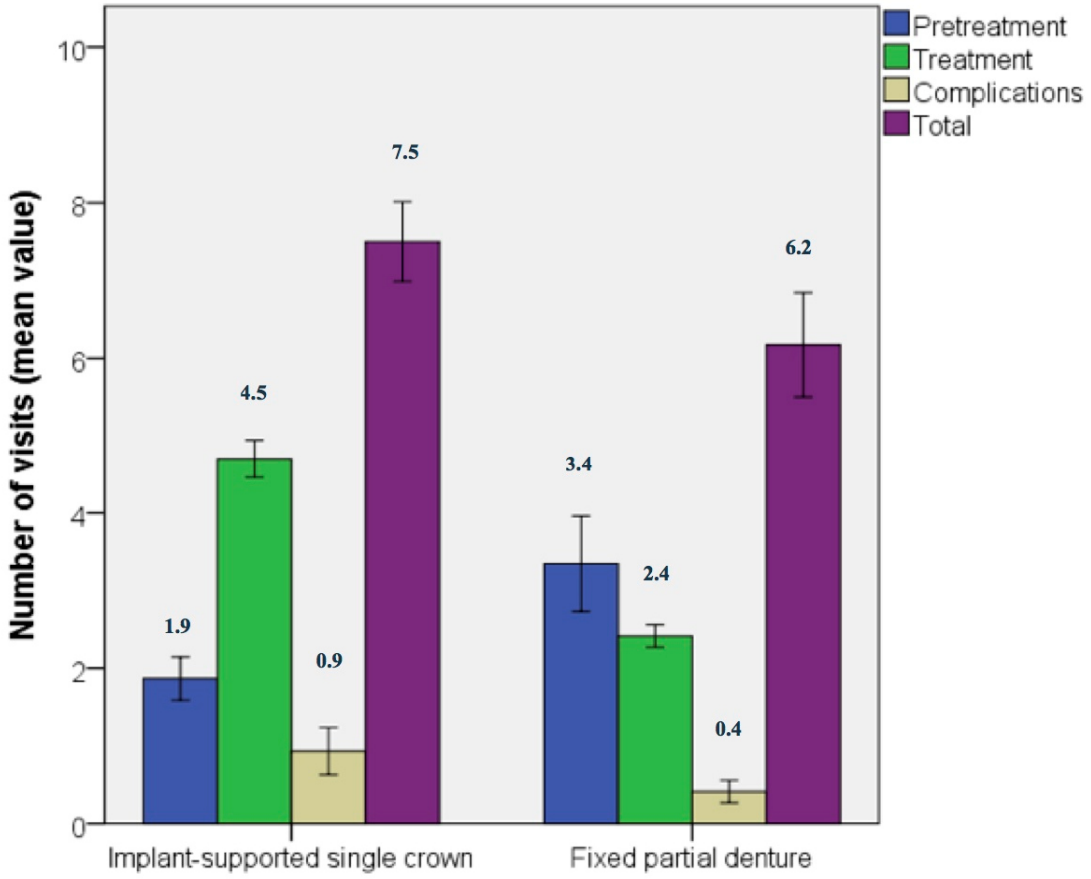

Figure 3: Mean values and standard deviations of the number of visits needed during the pretreatment and treatment phase ISC and FDP as well as for taking care of complications.

When the actual chairside time was calculated, it became obvious that the pretreatment was more time consuming for FDPs, whereas due to surgery, the treatment duration for ISC was statistically significantly higher (Table 5 and Figure 4). No statistically significant differences in total chairside times were found when the two groups were compared.

Table 5. Number of visits and duration (h)

		ISC	**FDP**	
Variable	Measure	Mean (± SD)	Mean (± SD)	p value
Pretreatment	Number of visits	1.87 (±1.53)	3.34 (±3.32)	0.084
	Treatment duration	1.23 (±1.04)	2.52 (±2.38)	0.029
Treatment	Number of visits	4.70 (±1.32)	2.41 (±0.78)	< 0.0001
	Treatment duration	3.63 (±0.99)	2.30 (±0.61)	< 0.0001
Complications	Number of visits	0.93 (±1.66)	0.41 (±0.78)	0.519
	Treatment duration	0.43 (±0.76)	0.20 (±0.46)	0.556
Total	Number of visits	7.50 (±2.80)	6.17 (±3.61)	0.032
	Treatment duration	5.30 (±1.80)	5.01 (±2.54)	0.219

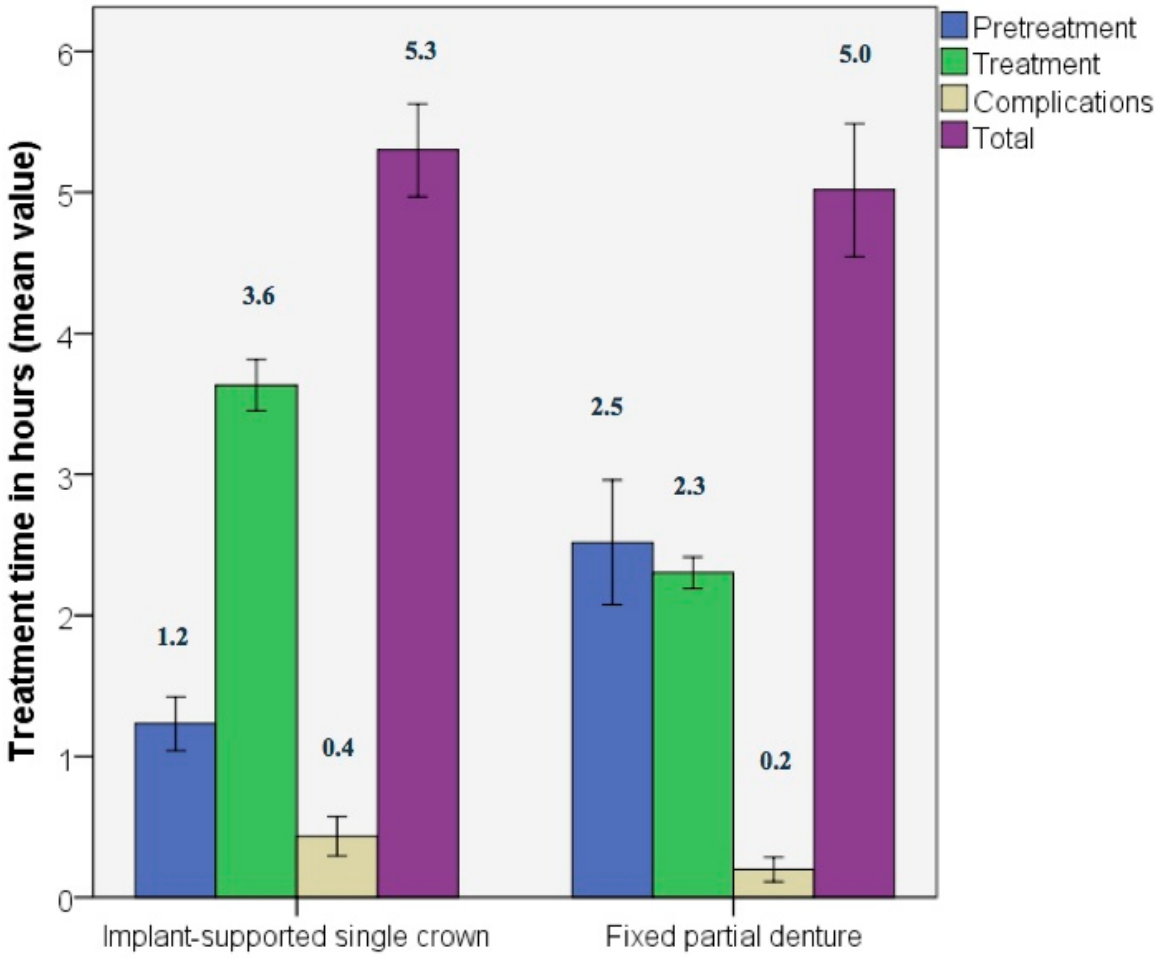

Figure 4: Mean values and standard deviations of the treatment time in hours needed during the pretreatment and treatment phase of ISC and FDP as well as for taking care of complications.

Economic differences between FDP and ISC treatment

Pretreatment fees and the costs for the dental technical work were statistically significantly higher in the FDP group (Table 6). Except for the costs of complications, which were low, ISC showed predominantly lower values than FDP. The last variable marked with a (*) symbol presents the total fees if a flat rate of CHF 50 for each visit would be added in consideration of opportunity costs (Brägger et al., 2005).

Table 6. Fees in Swiss Francs (CHF) *"The last variable marked with a (*) symbol presents the total fees if a flat rate of CHF 50 for each visit would be added in consideration of opportunity costs (Brägger et al.,2005)."*

	ISC	**FDP**	
Variable	Mean (± SD)	Mean (± SD)	p value
Pretreatment	278.63 (±306.18)	847.81 (±722.41)	0.001
Treatment	1775.72 (±265.75)	1802.69 (±597.19)	0.120
Complications	33.51 (±116.94)	20.20 (±79.58)	0.499
Material	730.02 (±411.64)	751.80 (±0.00)	0.488
Dental technical laboratory	1211.56 (±395.17)	1498.20 (±492.59)	0.000
Total	4005.11 (±820.97)	4194.83 (±1031.99)	0.509
Total including flat rate fees*	4380.11 (±864.84)	4503.45 (±1124.32)	0.667

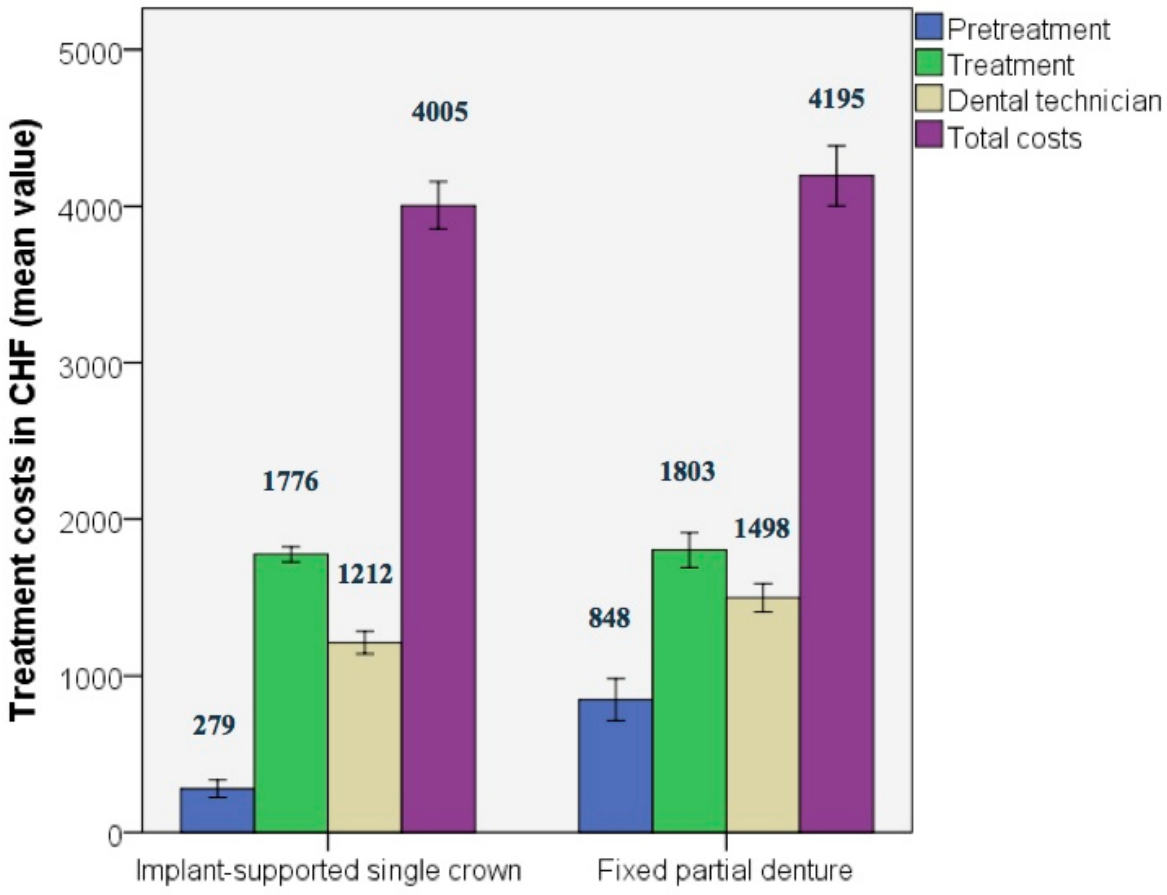

Figure 5: Mean values and standard deviations of the treatment costs needed during the pretreatment and treatment phases of ISC and FDP as well as for the dental technician.

Complications

A list of complication that occurred in the two treatment groups was presented in Table 7.

Table 7 Treatment complications

Complications with ISC	**n (%)**	**Complications with FDP**	**n (%)**
No complications	20 (66.7%)	No complications	20 (69.0%)
Infection	2 (6.7%)	Pulpitis of FDP abutment	1 (3.4%)
Healing disorder	1 (3.3%)	Apicectomy of FDP abutment	2 (6.9%)
Insufficient fit of suprastructure	2 (6.7%)	Fracture of provisional prosthes	2 (6.9%)
Loss or loosening of suprastructure	3 (10.0%)	Occlusal interference	3 (10.4%)
Diverse implant complications	1 (3.3%)	Excess of cement	1 (3.4%)
Occlusion interference of provisional prosthesis	1 (3.3%)		

Discussion

The aim of this study was to evaluate and compare the cost-effectiveness of two different treatment alternatives (ISC and FDP) for replacement of a single missing tooth in a private dental practice environment. This question is important for the involved members of the dental health care system (patients, dental suppliers, insurers and dentists), who may have differing perspectives and expectations.

Economic outcomes are commonly evaluated by cost-effectiveness ratio analyses, which estimate the relative efficiency of the alternatives by holding the outcome constant. This approach is frequently applied in health care to assess the cost-efficacy of competing therapies for similar health conditions, such as different treatment modalities for missing teeth (Torabinejad et al., 2007). As long as the outcome is the same for all alternative therapies, the approach is essentially a cost comparison, with the lowest cost alternative being preferred. The therapy that requires fewer resources, as measured by clinician time and training, and cost of materials, is more efficient (Salinas et al., 2007; Scheuber et al., 2012; Torabinejad et al., 2007).

A further study with the purpose of reviewing available literature on the health economic implications and cost-effectiveness of dental implants came to the conclusion that for single-tooth replacement, single-implant treatment was a cost-effective treatment option in comparison with a traditional three-unit fixed dental prosthesis (Vogel et al., 2013).

In the present investigation, ISC treatment required on average one additional visit compared to FDP treatment, but the actual chairside time of ±5 hours was equal in the groups. Pretreatment costs and costs for dental technicians were significantly lower in the ISC group. Except for complication costs, which were very low compared to the other costs, ISC showed lower values than FDP for treatment and material costs and also for total costs, the differences were statistically not significant. However, we only assessed initial costs, not lifetime costs, and for all comparisons made within this study, a sound periodontium was confirmed prior to treatment, based upon general clinical examination together with X-ray diagnostics.

Satisfaction of the patients with their dental treatment was not documented.

The results of the present study indicate that 33.3% of ISC patients and 31.0% of FDP patients experienced some kind of complication during treatment. In a similar study, the lowest percentage of complications occurred in single-crown therapy (25%), and the highest (35%) in 3-4unit FDP groups (De Boever et al., 2006). In a recent study on zirconia-based

restorations, the 5-year Kaplan-Meier survival probability was 98.3% for implant-supported crowns and 97.3% for tooth-supported crowns (Nejatidanesh et al., 2015). Therefore, implant-supported crowns seemed to be equally or less frequently affected by complications, but further studies are needed to assess exact values on long-term stability of both treatment modalities.

Apart from functionality and cost-efficiency, an important aspect is soft tissue esthetics, especially in the front tooth region. Using implant-supported crowns for single-tooth replacement in the anterior maxilla, it was possible to obtain esthetic peri-implant soft tissue results with ideal ridge forms with a minimum width of 5.5 mm (McGuire et al., 2015).

The relevant literature on the optimal therapy for the replacement of a single missing tooth clearly favors implant-supported single crowns (Antonarakis et al., 2014; Bateman et al., 2010; Beikler & Flemmig, 2015; Brägger et al., 2005; Fugazzotto 2009; Kim et al., 2011; Kim et al., 2014; Torabinejad et al., 2007; Vogel et al., 2013). ISC treatments resulted in superior long-term survival compared to FDPs, led to better improvements in oral health-related quality of life, and were found to be a more cost-effective treatment modality than FDP.

The present investigation focused on the cost-effectiveness of two common treatment modalities for single missing tooth replacement. The data were collected from a dental practice in Switzerland, and as the values were similar to those from another study on this topic (Brägger et al., 2005), the results can likely be seen as representative for the Swiss dental health care system. The precise acquisition of prices and treatment hours and the long follow-up times can be regarded as additional strengths of our study. The sample size of 59 cases could be seen as a limitation of this study, especially as the total costs were clearly in favor of the ISC treatment, but statistically there was no significant difference between the two groups. However, in agreement with previous studies, our results provided further evidence of a better cost-effectiveness ratio for ISC compared to FDP treatment (Zitzmann et al., 2013).

In conclusion, the emerging consensus from the present study and from the available literature is that for single-tooth replacement, crowns on dental implant represents a cost-saving, longer-lasting and quality-of-life-improving treatment option in comparison to a tooth-supported 3-unit fixed dental prosthesis. In particular in clinical situations which involves teeth with minor or no restorations and/ or favorable bone conditions for standard placement, reconstruction with implants is to be recommended.

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