Economic Evaluation of Single-Tooth Replacement: Dental Implant Versus Fixed Partial Denture

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Purpose: *This study assessed the cost-effectiveness from a societal perspective of a dental implant compared with a three-unit tooth-supported fixed partial denture (FPD) for the replacement of a single tooth in 2010.* ***Materials and Methods:*** *A decision tree was developed to estimate cost-effectiveness over a 10-year period. The survival rates of single-tooth implants and FPDs were extracted from a meta-analysis of single-arm studies. Medical costs included initial treatment costs, maintenance costs, and costs to treat complications. Patient surveys were used to obtain the costs of the initial single-tooth implant or FPD. Maintenance costs and costs to treat complications were based on surveys of seven clinical experts at dental clinics or hospitals. Transportation costs were calculated based on the number of visits for implant or FPD treatment. Patient time costs were estimated using the number of visits and time required, hourly wage, and employment rate. Future costs were discounted by 5% to convert to present values.* ***Results:*** *The results of a 10-year period model showed that a single dental implant cost US $261 (clinic) to $342 (hospital) more than an FPD and had an average survival rate that was 10.4% higher. The incremental cost-effectiveness ratio was $2,514 in a clinic and $3,290 in a hospital for a prosthesis in situ for 10 years. The sensitivity analysis showed that initial treatment costs and survival rate influenced the cost-effectiveness. If the cost of an implant were reduced to 80% of the current cost, the implant would become the dominant intervention.* ***Conclusion:*** *Although the level of evidence for effectiveness is low, and some aspects of single-tooth implants or FPDs, such as satisfaction, were not considered, this study will help patients requiring single-tooth replacement to choose the best treatment option.* INT J ORAL MAXILLOFAC IMPLANTS 2014;29:600–607. doi: 10.11607/jomi.3413

Key words: *cost-effectiveness analysis, dental implant, economic evaluation, partial denture, single-tooth loss*

The need to efficiently allocate health care resources is increasing as a result of limited resources and rapidly increasing expenditures, and dentistry is no exception. Health technology assessment (HTA) helps to efficiently allocate resources; however, HTA is still at an early stage in dentistry.

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South Korea has a national health insurance (NHI) system with universal coverage for the Korean population.[1,2] However, NHI coverage of dental services is relatively poor. Therefore, the economic burden for dental services on Korean patients is high. In addition, most prosthetic treatments other than dentures for aging patients are not covered by the NHI in Korea, although prosthetic treatment is common: 27.2% of Koreans have received at least one prosthetic treatment. Of these, 2.7% received implants and 12.9% needed further prosthetic treatment, mainly because prosthetic treatment was a financial burden.[3] This high economic burden for prosthetic treatment requires efficient choices.

Following the loss of a single tooth, the gap can be restored with a dental implant or a fixed partial denture (FPD). A dental implant can treat the missing tooth without damaging the adjacent teeth, regardless of the condition of the surrounding teeth. However, implant treatment is expensive, complicated, lengthy, and affected by the bone condition. In addition, there can be mechanical or technical problems, such as fracture of the prosthesis, screw, or artificial root. There are also biologic risks, such as peri-implantitis and mandibular nerve damage.[4] An FPD replaces a missing tooth by permanently joining the artificial unit to adjacent natural teeth. FPD treatment takes only about 2 weeks at most. Because it uses a patient's own teeth, an FPD may feel more comfortable than an implant. An FPD is also useful when implant surgery is impossible because of health problems. However, the adjacent natural teeth (abutment teeth) must be in good condition, and preparation of the teeth to serve as abutments may expose pulp and increase sensitivity. In addition, there are differences between an implant crown and an FPD in prosthetic survival rate, complications, satisfaction, quality of life, cost, and management.[4–7] Therefore, evaluation and comparison of the health outcomes and costs associated with implant and FPD treatment can help consumers, clinicians, and policy makers to reach informed decisions.[8] However, few studies have evaluated the cost-effectiveness of single-tooth replacement.[7]

This study assessed the cost-effectiveness from a societal perspective of a dental implant compared with a three-unit FPD in patients who required replacement of a single tooth in 2010.

MATERIALS AND METHODS

Economic Analysis Method

Economic evaluation is a method of evaluating and comparing the outcomes and costs of interventions.[9] Thus, it includes the tasks of identifying, measuring, valuing, and comparing the health outcomes and costs of interventions being considered. Decision analytic modeling provides a framework to consider the possible events that the study population may experience and identifies how the intervention may influence the events. The prevalent models used in economic evaluation of health care are the decision tree and the Markov model.[10] In the current study, a decision tree was used to determine the possible prognosis by a series of pathways following treatment with a dental implant or a three-unit FPD.

Economic evaluations in health care are mostly cost-effectiveness or cost-utility analyses, in which the results are presented as the incremental cost effectiveness ratio (ICER).[10] ICER indicates the difference in cost (net cost) per the difference in outcomes (net effectiveness).[9,11]

$$\text{ICER} = \frac{\text{Effectiveness}_A - \text{Effectiveness}_B}{\text{Cost}_A - \text{Cost}_B} = \frac{\text{Net effectiveness}}{\text{Net cost}}$$

An economic evaluation based on ICER needs a threshold to judge its worth. If the unit of effectiveness is life years gained (LYG) or quality-adjusted life years (QALYs), an explicit or implicit threshold (eg, US$50,000 or £20,000 to £30,000 for one additional QALY) can be used to determine whether an intervention is cost effective.[12] There is no universal standard for cost-effectiveness ratios because of the different health care systems and economic environments of different countries. However, when an intervention is both more effective and less costly than an alternative, the result of the economic evaluation is definitive—that is, the intervention is the dominant strategy.

This study was conducted by considering the checklist for economic evaluations in health care.[10] The checklist was also used to assess the quality of economic studies in a previous study that reviewed the economic aspects of dental implant treatment.[13]

Model Overview

The study population consisted of patients who had lost a single tooth. Patients who could receive either a dental implant or a three-unit FPD and could choose between these treatment options were included. Only patients who had natural teeth on both sides of the missing tooth were considered. Patients who received prosthetic treatments on more than two adjacent teeth were not included. Participants were not limited by age, gender, or condition of the tooth that had been lost.

A decision tree over a 10-year period was developed to estimate cost-effectiveness (Fig 1). Patients who have lost a single tooth can be treated with a dental implant or with a three-unit FPD. After a prosthetic treatment fails, there are three choices: restoration with an implant, restoration with an FPD, or no reconstruction. Future costs were discounted at 5% to convert present values in the base case analysis according to Korean economic evaluation guidelines. The treatment periods were assumed to be 6 months for an implant and 10 days for three-unit FPDs and were included in the study period. The costs were all converted into US dollars.

Outcome Measure

The outcome was measured by survival rate, which was defined as an implant or FPD in situ 10 years after treatment, irrespective of its condition. The survival rates of single-tooth implants and FPDs were extracted from a meta-analysis of single-arm studies.[14–31]

Cost Data and Assumptions

The economic evaluation was conducted from a societal perspective and included the following (Table 1). Medical costs, transportation costs, and patient time were considered as costs of implant and FPD

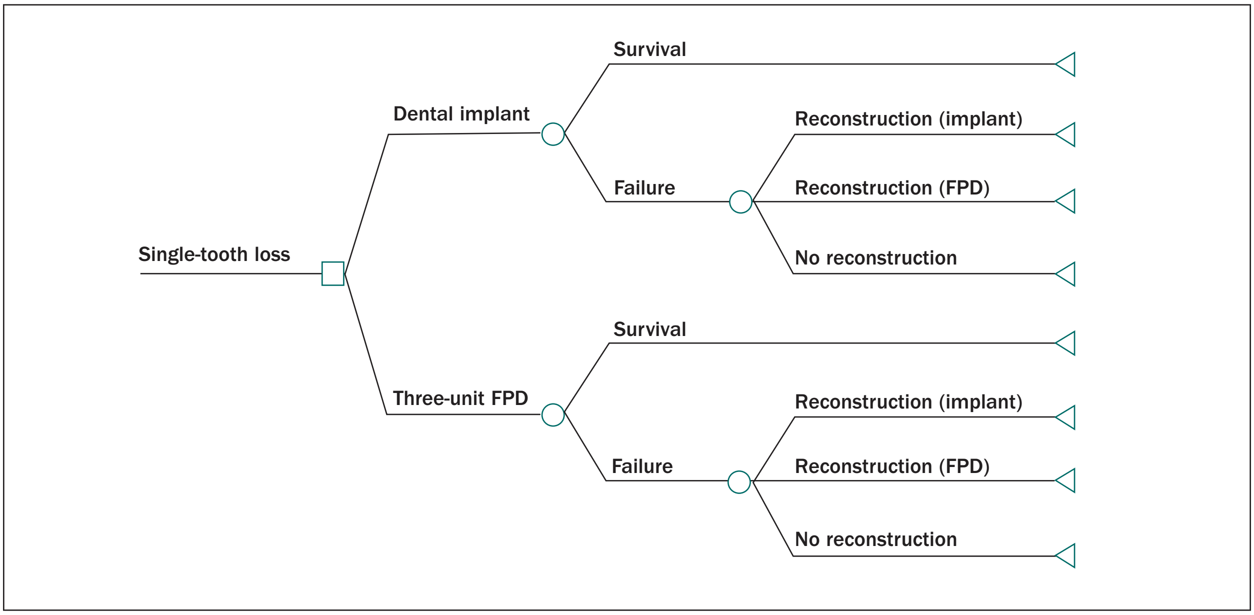

Fig 1 Model structure: decision tree.

Table 1 Cost Categories and Definitions

Cost categories	Definition	Inclusion in this study	Note
Medical costs (formal)	Initial treatment cost, cost of re-treatment after failure, maintenance costs, costs of treating complication	Included	The proportion of patients requiring outpatient drugs is not significant, so prescription costs are not considered
Medical costs (informal)	Costs for over-the-counter drugs, medical device, health supplements, and health food resulting from loss of a single tooth	Not included	The informal medical costs in patients who lose a single tooth are considered insignificant
Patient time costs	Patient time costs for treatment and management of implant or FPD	Included	Time costs for the treatment of complications are excluded (no data)
Transportation costs	Transportation costs for dental clinic or hospital visit for treatment and management of implant or FPD	Included	Transportation costs to visit a medical institution for treatment of a complication are excluded (no data)
Caregiver costs	Caregiver costs for patients who lost a single tooth	Not included	Rare
Productivity loss costs	Productivity loss as a result of morbidity or premature death from a complication of an implant or FPD	Not included	There were no deaths caused by complications of prosthetic treatments

treatment. Productivity lost because of morbidity or premature death was assumed to be the same. Medical costs included initial treatment, maintenance, and treatment of complications. Patient surveys were used to determine the cost of the initial treatment of single-tooth implants or FPDs.

Cost and medical utilization differ depending on the size of medical institution. Therefore, the analysis was conducted and the results are presented in both clinic and hospital settings (Table 2). The medical cost, transportation costs, and patient time costs for dental implants and three-unit FPDs were expected to differ in clinic and hospital settings.

Maintenance costs and the costs to treat complications were based on surveys of seven clinical experts from dental clinics or hospitals. These surveys indicated that 80% of implants were restored with another implant, but only 50% of three-unit FPDs were restored with another three-unit FPD. Based on these rates, the expected cost of re-treatment after failure of each prosthetic treatment was calculated. If a three-unit FPD fails, the abutment teeth on both sides are

Table 2 Input Data in the Economic Model

Parameter	Clinic	Hospital	Source
Survival rate (effectiveness)			
Implant (%)	91.7 [97.4, 85.9]		Meta-analysis
FPD (%)	81.3 [89.7, 71]		Meta-analysis
Initial treatment costs			
Implant ($)	1,616	2,708	Patient survey
FPD ($)	1,308	1,805	Patient survey
Re-treatment costs after implant failure			
Implant ($)	1,616	2,708	Patient survey, clinical expert opinion
FPD ($)	1,038	1,805	Patient survey, clinical expert opinion
Re-treatment costs after FPD failure			
Implant ($)	3,574	6,020	Patient survey, clinical expert opinion
FPD ($)	2,076	3,610	Patient survey, clinical expert opinion
Visit schedule (for treatment)			
Implant (no. of visits)	8 [5]		Clinical experts survey
FPD (no. of visits)	3 [2]		Clinical experts survey
Visit schedule (for maintenance)			
Implant (no. of visits)	13		Clinical experts survey
FPD (no. of visits)	12		Clinical experts survey
Maintenance unit costs ($)	14		Clinical experts survey
Transportation unit costs ($)	1	2	Korea Health Panel
Weighted average wage ($)	7		Korean Ministry of Employment and Labor
Complication treatment costs			
Prosthetic fracture			
Implant			
Proportion (%)	0.4		Clinical experts survey
Treatment costs ($)	36		Clinical experts survey
FPD			
Proportion (%)	2.1		Clinical experts survey
Treatment costs ($)	903		Clinical experts survey
Peri-gingivitis			
Implant			
Proportion (%)	9.7		Clinical experts survey
Treatment costs ($)	18		Clinical experts survey
FPD			
Proportion (%)	0.5		Clinical experts survey
Treatment costs ($)	18		Clinical experts survey
Bone loss			
Implant			
Proportion (%)	6.3		Clinical experts survey
Treatment costs ($)	1,108		Clinical experts survey
Secondary caries			
FPD			
Proportion (%)	9.5		Clinical experts survey
Treatment costs ($)	72		Clinical experts survey

Values in brackets were derived from the sensitivity analysis. Exchange rate: US $1 = 1,108 KRW (2010).

often removed; therefore, the cost to replace a three-unit FPD with a larger FPD was assumed to be twice the cost of the original FPD. The cost to replace a three-unit FPD with dental implants was assumed to be one-third of the cost of the original FPD plus the cost to replace the abutment teeth, which is twice the cost of a dental implant. The main complications of a dental implant were considered to be loss of surrounding bone, prosthesis fracture, and peri-gingivitis. Prosthesis fractures, peri-gingivitis, and dental caries were considered to be complications of three-unit FPDs. Although the number of visits and unit cost per visit varied among clinics, the cost of regular maintenance was determined by using the mean values.

Transportation costs were calculated based on the number of visits for an implant or an FPD. The 2010 inflation-adjusted one-way fare for dental clinics and dental hospitals reported in the 2008 Korea Health Panel were used as unit costs.

Patient time costs were estimated according to the number of visits and time required, hourly wage, and employment rate.

Sensitivity Analysis

In economic evaluations, uncertainty exists. To examine the sensitivity, the parameters of survival rate, visit schedules, initial treatment costs, and the discount rate were varied and then considered in sensitivity analysis. In addition, the initial treatment cost at which a dental implant becomes the dominant strategy (more effective and less costly) was calculated.

RESULTS

Survival Rates of Implants and FPDs

No head-to-head trials have compared single-tooth implants and three-unit FPDs. Therefore, a meta-analysis of single-arm studies of each prosthetic treatment was used in this study. The estimated 10-year survival rates after treatment were 91.7% (95% confidence interval, 85.9% to 97.4%) for an implant and 81.3% (95% confidence interval, 71% to 89.1%) for a three-unit FPD in the random-effect model.[3]

Cost Estimates

The mean cost of a dental implant was $1,616 in a clinic and $2,708 in a hospital, and the mean cost of an FPD was $1,308 in a clinic and $1,805 in a hospital. An analysis of the incidence and cost of treating complications from the clinical expert survey showed that bone loss was more costly than other implant complications, whereas porcelain veneer fracture and secondary caries accounted for most of the cost of treating complications with three-unit FPDs.

The medical cost that accounts for re-treatment costs resulting from failure, maintenance, and treatment of complications as well as the procedure cost ranged from $2,064 in a clinic to $3,298 in a hospital for a dental implant and from $1,802 in a clinic to $2,965 in a hospital for a three-unit FPD (Table 3). Because visits to a medical institution for dental implant procedures and implant maintenance were more frequent, the patient time cost and the transportation costs for a dental implant were higher than those for a three-unit FPD.

Incremental Cost-Effectiveness Ratio

Dental implants cost $261 (clinic) to $342 (hospital) more than three-unit FPDs, and implant survival rates were 10.4% higher. The incremental cost-effectiveness ratio was therefore $2,514 in a clinic and $3,290 in a hospital for a prosthesis preserved for 10 years.

Sensitivity Analysis

The sensitivity analysis showed that the visit schedule and discount rate did not affect the incremental cost-effectiveness ratio (less than 2%), but the initial treatment costs and the survival rate did (Fig 2). In a sensitivity analysis in which the cost of a dental implant was reduced to 80% of the current cost, the difference in the cost of a dental implant and a three-unit FPD was reduced to $255 in a clinic and $361 in a hospital. These changes would make dental implants the dominant treatment option, with their higher survival rate and lower cost. At less than 84% of the current cost of a dental implant, a single-tooth implant becomes the dominant strategy. At an implant cost of $1,357 in a clinic and $2,356 in a hospital, the differences in costs of a dental implant and FPD would be $319 and $551, respectively, which would make a dental implant less costly and more effective as a solution for single-tooth loss.

DISCUSSION

There are few economic evaluations of interventions for single-tooth loss.[13] Previous studies[5,6] stated that dental implants are more effective than three-unit FPDs and cost less, unlike the current findings in Korea. Bouchard et al developed a decision tree with a 20-year analysis period to conduct the economic evaluation of a dental implant and a three-unit FPD in patients missing a single tooth.[5] When looking at effectiveness as a success rate, the medical costs of successfully completing prosthetic treatment were compared. Although the authors did not conduct an incremental analysis, the dental implant was the dominant strategy, with higher effectiveness and lower additional cost. Brägger et al analyzed the costs of a single-tooth implant and FPD, taking into account physician costs, material costs, test costs, complication costs, and opportunity costs, using retrospective patient data.[6] When the costs of each treatment were compared, the total costs and opportunity costs of an FPD were higher.

These differences in the results are attributable to the smaller differences in cost of a dental implant and three-unit FPD in Europe than in Korea. In the Bouchard et al study, the absolute treatment costs of implants and FPDs were high, but the difference was less than 10%, whereas the difference in the treatment cost of a dental implant and three-unit FPD found in this study was more than 50%. In the present study, the sensitivity analysis showed that the total cost of a dental implant, including re-treatment cost, was less than the

Table 3 Base Case Analysis Results of the Comparison of Implant and FPD in Patients with Single-Tooth Loss

	Implant	FPD	Difference	Incremental cost-effectiveness ratio
Clinic				
Effectiveness (survival rate, %)	91.70%	81.30%	10.40%	
Total costs ($)	2,064	1,802	261	2,514
Medical costs ($)	1,888	1,673	215	
Time costs ($)	162	120	42	
Transportation costs ($)	14	10	4	
Hospital				
Effectiveness (survival rate, %)	91.70%	81.30%	10.40%	
Total costs ($)	3,298	2,956	342	3,290
Medical costs ($)	3,014	2,746	268	
Time costs ($)	240	178	62	
Transportation costs ($)	44	32	12	

Exchange rate: US $1 = 1,108 KRW (2010).

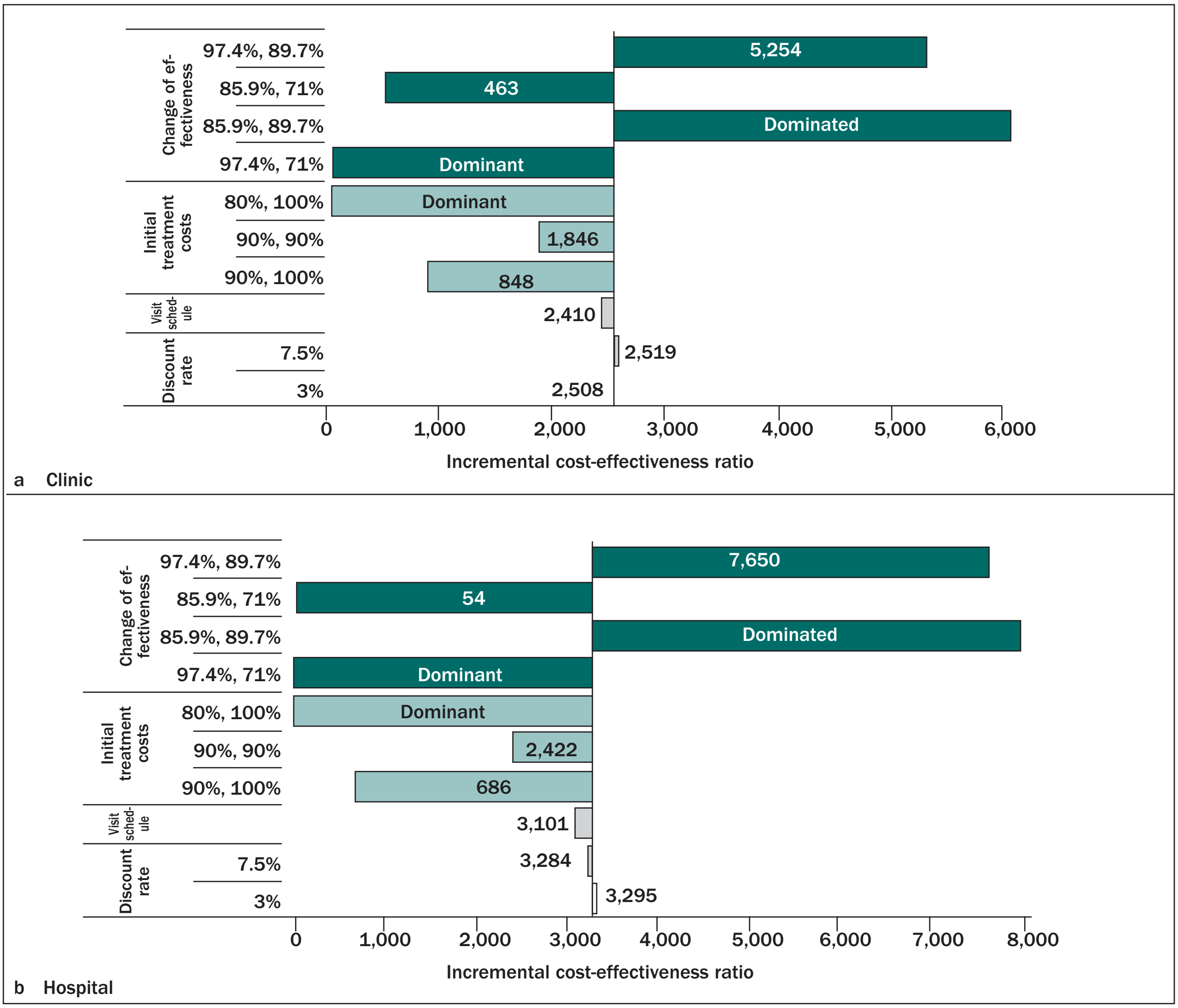

Fig 2 Sensitivity analyses comparing dental implant and three-unit FPDs in patient with single-tooth loss (*a*) in a clinic and (*b*) in a hospital. Change of effectiveness = survival rate of implant and FPD, respectively; initial treatment costs = percentage change of costs of implant and FPD, respectively. Exchange rate: US $1 = 1,108 KRW (2010).

total cost of an FPD if the treatment cost of an implant is reduced to 80% of the current cost, which would decrease the difference between the cost of an implant and FPD to within 20%. In other words, a dental implant would become more effective with a lower cost. This result is consistent with previous studies done elsewhere. The cost of dental implants has recently decreased as a result of technological advances and the introduction of new materials. This would make a dental implant more efficient from an economic point of view.

A dental implant has more factors that affect the survival rate than a three-unit FPD, such as the quantity and quality of residual bone, anatomical limitations, and the patient's current health status; therefore, it is difficult to apply an average survival rate to all patients. This difficulty limits comparison of the cost-effectiveness of implants and FPDs among patients in different clinical situations. For this reason, target patients in this study were limited to ensure patient homogeneity; care should be taken in interpreting the result.

Partially edentulous patients, who account for most prosthodontic patients, were not considered in this study. Because implant prosthetic treatments and FPDs are also placed in partially edentulous patients, these treatments should be compared in partially edentulous patients.

The level of evidence for effectiveness is low because no head-to-head trials have compared single-tooth implants and three-unit FPDs. Therefore, this study is limited in its evaluation of the clinical superiority of implants versus FPDs.

This economic evaluation was performed with a 10-year analysis period. However, the survival rate after re-treatment of a failed prosthesis was not considered because of limited data.

The economic evaluation in this study did not consider all aspects of a single-tooth implant or FPD, such as satisfaction. The ability to treat regardless of the condition of surrounding teeth and without damaging adjacent teeth is the main advantage of implant treatment, and the esthetic advantages are not reflected in the economic evaluation. Therefore, sufficient information has to be provided to patients in the clinical setting so that they can make an informed choice.

The cost data derived here may not be representative of all situations. In addition, the patient survey could have been influenced by recall bias. This study tried to overcome these limitations by validating actual costs from experts at several clinics or hospitals and by conducing sensitivity analyses.

There are some challenges to conducting an economic evaluation in dentistry. First, generally, the final outcome, such as LYG or QALYs, is the recommended effectiveness in an economic evaluation of health care. In dentistry, however, it is difficult to present outcomes as LYG or QALYs.[13] In this study, effectiveness was defined as prosthesis survival for 10 years. Prosthesis survival for 10 years is difficult to compare to health outcomes of other economic evaluations. In addition, it is difficult to estimate the incremental cost for a prosthesis preserved for 10 years. More importantly, no formal rule has been used to determine whether an intervention is cost-effective. This analysis offers the additional costs for prostheses preserved for 10 years, and patients must compare the result and their willingness to pay for a prosthesis preserved for 10 years. If a strategy is dominant (more effective and less costly), however, the results are easy to interpret. In a previous study, the single-tooth implant was the dominant intervention.[5] In the current study, if the cost of an implant were reduced to 80% of the current cost, the implant would become the dominant intervention in single-tooth loss. Quality-adjusted tooth years (QATYs) and quality-adjusted prosthesis years (QAPYs) were developed to consider both prosthesis survival and quality of life.[32,33] However, QATYs or QAPYs have been used in very few economic evaluations of prosthetic dentistry.[34] In addition, no studies have yet examined the decision rules using QATYs or QAPYs, and no studies have yet mapped these indicators to generic measurements, such as the EQ-5D or Health Utilities Index 3 (HUI3), which are commonly used in an economic evaluation of health care.[13]

Few high-quality studies have compared the effectiveness of dental services. Head-to-head, randomized, controlled trials that provide unbiased effectiveness and safety data are rare in dentistry. Therefore, the level of evidence for effectiveness is likely to be low.

In addition, epidemiologic studies are insufficient for economic evaluations. Because transition probability is often extracted from epidemiologic studies in economic evaluations, more assumptions are required without sufficient data, and more uncertainty is therefore inherent in the result.

Finally, cost data are difficult to obtain because most dental services are not reimbursed. Although cost data could be collected from medical institutions, the gaps between costs at different medical institutions are high. Therefore, additional efforts are required to set representative costs for dental services.

This study conducted an economic evaluation with these limitations. However, this study considered the costs from a societal perspective, including medical costs caused by complications, time costs, and transportation costs, through conducting clinician and patient surveys and presented extensive sensitivity analyses to reflect the uncertainty of the variables. Therefore, this study is expected to promote HTA in dentistry.

CONCLUSIONS

The economic evaluation in this study showed that dental implants cost from $251 to $325 more than three-unit fixed partial dentures, depending on treatment location, and also had survival rates that were 10.4% higher. Patients want more effective intervention but have limited budgets; this knowledge of the incremental cost for the additional effectiveness should help patients make an informed choice. This study should be helpful in helping patients with single-tooth loss in South Korea choose the best treatment option, where the coverage rate of the national health service is low and the economic burden on consumers is high, although the level of evidence for effectiveness is low and some aspects of single-tooth implants or fixed partial dentures, such as satisfaction, were not considered.

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REFERENCES

1. Kim Y, Yang B. Relationship between catastrophic health expenditures and household incomes and expenditure patterns in South Korea. Health Pol 2011;100(2–3):239–246.
2. Ruger JP, Kim HJ. Out-of-pocket healthcare spending by the poor and chronically ill in the Republic of Korea. Am J Pub Health 2007;97(5):804–811.
3. Kim Y, Park SY, Park J, et al. Economic Evaluation of Dental Implants in Korea. Seoul, Korea: National Evidence-Based Healthcare Collaboration Agency, 2011.
4. Bragger U, Karoussis I, Persson R, Pjetursson B, Salvi G, Lang N. Technical and biological complications/failures with single crowns and fixed partial dentures on implants: A 10-year prospective cohort study. Clin Oral Implants Res 2005;16(3):326–334.
5. Bouchard P, Renouard F, Bourgeois D, Fromentin O, Jeanneret MH, Beresniak A. Cost-effectiveness modeling of dental implant vs. bridge. Clin Oral Implants Res 2009;20(6):583–587.
6. Brägger U, Krenander P, Lang NP. Economic aspects of single-tooth replacement. Clin Oral Implants Res 2005;16(3):335–341.
7. Torabinejad M, Anderson P, Bader J, et al. Outcomes of root canal treatment and restoration, implant-supported single crowns, fixed partial dentures, and extraction without replacement: A systematic review. J Prosthet Dent 2007;98(4):285–311.
8. Sox HC, Goodman SN. The Methods of Comparative Effectiveness Research. Ann Rev Pub Health 2012;33(1):425–445.
9. Gold MR, Siegel JE, Russell LB, Weinstein MC. Cost-Effectiveness in Health and Medicine. New York: Oxford University Press, 1996.
10. Drummond M, Sculpher M, Torrance G, O'Brien B, Stoddart G. Methods for the Economic Evaluation of Health Care Programmes. New York: Oxford University Press, 2005.
11. Berger M, Bingefors K, Hedblom E, Pashos C, Torrance G (eds). Health Care Cost, Quality, and Outcomes. ISPOR Book of Terms. Lawrence, NJ: International Society for Pharmacoeconomics and Outcomes Research, 2003.
12. Towse A, Pritchard C, Devlin N. Cost-Effectiveness Thresholds: Economic and Ethical Issues. London: King's Fund and Office of Health Economics, 2002.
13. Vogel R, Smith-Palmer J, Valentine W. Evaluating the health economic implications and cost-effectiveness of dental implants: A literature review. Int J Oral Maxillofac Implants 2013;28(2):343–356.
14. Bonde MJ, Stokholm R, Isidor F, Schou S. Outcome of implant-supported single-tooth replacements performed by dental students. A 10-year clinical and radiographic retrospective study. Eur J Oral Implantol 2010;3(1):37–46.
15. Dhanrajani PJ, Al-Rafee MA. Single-tooth implant restorations: A retrospective study. Implant Dent 2005;14(2):125–130.
16. Engquist B, Nilson H, Astrand P. Single-tooth replacement by osseointegrated Brånemark implants. A retrospective study of 82 implants. Clin Oral Implants Res 1995;6(4):238–245.
17. Evian CI, Emling R, Rosenberg ES, et al. Retrospective analysis of implant survival and the influence of periodontal disease and immediate placement on long-term results. Int J Oral Maxillofac Implants 2004;19(3):393–398.
18. Johnson RH, Persson GR. A 3-year prospective study of a single-tooth implant—Prosthodontic complications. Int J Prosthodont 2001;14(2):183–189.
19. Kim YK, Kim SG, Yun PY, Hwang JW, Son MK. Prognosis of single molar implants: A retrospective study. Int J Periodontics Restorative Dent 2010;30(4):401–407.
20. Koo KT, Wikesjo UME, Park JY, et al. Evaluation of single-tooth implants in the second molar region: A 5-year life-table analysis of a retrospective study. J Periodontol 2010;81(9):1242–1249.
21. Lee DJ, Harlow RE, Yuan JC, Sukotjo C, Knoernschild KL, Campbell SD. Three-year clinical outcomes of implant treatments provided at a predoctoral implant program. Int J Prosthodont 2011;24(1):71–76.
22. Levin L, Sadet P, Grossmann Y. A retrospective evaluation of 1,387 single-tooth implants: A 6-year follow-up. J Periodontol 2006;77(12):2080–2083.
23. Mayer TM, Hawley CE, Gunsolley JC, Feldman S. The single-tooth implant: A viable alternative for single-tooth replacement. J Periodontol 2002;73(7):687–693.
24. Ribeiro FS, Pontes AEF, Marcantonio E, Piattelli A, Neto RJB, Marcantonio E Jr. Success rate of immediate nonfunctional loaded single-tooth implants: Immediate versus delayed implantation. Implant Dent 2008;17(1):109–117.
25. Priest G. Single-tooth implants and their role in preserving remaining teeth: A 10-year survival study. Int J Oral Maxillofac Implants 1999;14(2):181–188.
26. Roediger M, Gersdorff N, Huels A, Rinke S. Prospective evaluation of zirconia posterior fixed partial dentures: Four-year clinical results. Int J Prosthodont 2010;23(2):141–148.
27. Romeo E, Lops D, Margutti E, Ghisolfi M, Chiapasco M, Vogel G. Long-term survival and success of oral implants in the treatment of full and partial arches: A 7-year prospective study with the ITI dental implant system. Int J Oral Maxillofac Implants 2004;19(2):247–259.
28. Simon RL. Single implant-supported molar and premolar crowns: A ten-year retrospective clinical report. J Prosthet Dent 2003;90(6):517–521.
29. Valderhaug J, Jokstad A, Ambjornsen E, Norheim PW. Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent 1997;25(2):97–105.
30. van Heumen CCM, Tanner J, van Dijken JWV, et al. Five-year survival of 3-unit fiber-reinforced composite fixed partial dentures in the posterior area. Dent Mater 2010;26(10):954–960.
31. Vigolo P, Givani A. Clinical evaluation of single-tooth mini-implant restorations: A five-year retrospective study. J Prosthet Dent 2000;84(1):50–54.
32. Jacobson JJ, Maxson BB, Mays K, Kowalski CJ. A utility analysis of dental implants. Int J Oral Maxillofac Implants 1992;7(3):381–388.
33. Sendi P, Palmer A, Marinello C. Health state utilities in dentistry: A review. Acta Med Dent Helvet 1997;2(10):243–248.
34. Zitzmann NU, Marinello CP, Sendi P. A cost-effectiveness analysis of implant overdentures. J Dent Res 2006;85(8):717–721.