Agenesis of Maxillary Lateral Incisor and Tooth Replacement: Cost-Effectiveness of Different Treatment Alternatives

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Purpose: To evaluate the long-term cost-effectiveness of five treatment alternatives for maxillary lateral incisor agenesis where space maintenance and tooth replacement are indicated. ***Materials and Methods:*** The following treatment modalities were considered: single-tooth implant-supported crown, resin-bonded fixed partial denture (FPD), cantilever FPD, full-coverage FPD, and autotransplantation. The cost-effectiveness for each treatment modality was determined as the ratio of the outcome of each modality divided by the cost. Direct costs, clinical and laboratory, were calculated based on national fee schedules and converted to international dollars using purchasing power parity exchange rates. Outcomes were based on the most recently published long-term (10-year) survival rates. Sensitivity analyses were carried out, testing the robustness of the cost-effectiveness analysis. ***Results:*** The five treatment modalities ranked in the following order from most to least cost-effective: autotransplantation, cantilever FPDs, resin-bonded FPDs, single-tooth implants and implant-supported crowns, and full-coverage FPDs. Sensitivity analysis illustrated that the cost-effectiveness analysis was reliable in identifying autotransplantation as the most and full-coverage FPDs as the least cost-effective treatment modalities. ***Conclusions:*** When replacing a missing maxillary lateral incisor, the most cost-effective, long-term treatment modality is autotransplantation, whereas the least cost-effective is full-coverage FPDs. However, factors such as patient age, the state of the dentition, occlusion, and tooth conservation should also influence the choice of restoration. *Int J Prosthodont 2014;27:257–263. doi: 10.11607/ijp.3851*

Agenesis of the maxillary lateral incisors is a condition encountered by dental professionals in clinical practice. Its reported prevalence varies from 0.8% to 2%, depending on the population studied.[1] Treatment can involve orthodontic space closure resulting in substitution of the missing lateral incisor by the canine[2,3] or replacement of the missing lateral incisor.[4] Both approaches aim for long-term success, and the best esthetic and functional outcome, and they rely on thorough planning and the collaboration of a multidisciplinary dental team. The choice of treatment depends on many factors, such as intermaxillary and intramaxillary relationships, soft tissue characteristics, patient facial esthetics, and the size, shape, and color of teeth,[5] all of which play an important role in decision making. Similarly, other factors influencing treatment choice may include specialist education, finances, and patient and practitioner preferences. Clinical reports show satisfactory results with both space-closing and space-maintaining approaches with proper patient selection.[6]

In cases where clinical indications dictate maintenance of the maxillary lateral incisor space, the available options for the replacement of this tooth are numerous, including resin-bonded fixed partial dentures (FPDs), cantilever FPDs, conventional full-coverage FPDs, removable partial dentures, single-tooth implants, or autotransplantation. When replacement of a missing maxillary lateral incisor is planned, adjunctive orthodontic treatment is often required to redistribute or open the space for the replacement dental unit, followed by a prosthetic restoration or dental autotransplantation. Each treatment option presents different esthetic, functional, and biologic

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advantages and disadvantages, lifelong follow-up, and maintenance of the treatment result that involve varying costs and different survival and success rates.[6–8]

As questions arise on the costs and benefits of different treatments, economic evaluation is becoming an integral component of health research in recent years,[9] since value for money is being sought in treatments that are expected to have lifelong results.[10] To date, no published studies compare the overall cost of different treatment alternatives in cases of missing maxillary lateral incisors from a long-term perspective.[11] Such a study requires a formal cost-effectiveness analysis—a form of economic evaluation in which the costs and effects (defined by a measurable outcome) of an intervention designed to prevent, diagnose, or treat a disease are calculated and compared with an alternative strategy to achieve the same goals.[12]

The aim of this study was to evaluate and compare the long-term cost-effectiveness of the different treatment alternatives in cases of maxillary lateral incisor agenesis where space maintenance and tooth replacement are indicated.

Materials and Methods

Treatment Strategy

Five treatment modalities for the replacement of congenitally missing maxillary incisors were considered for the present study: a single-tooth implant-supported crown, resin-bonded FPD, cantilever FPD, full-coverage FPD, and autotransplantation. Only fixed treatment modalities were considered, and thus removable partial dentures and orthodontic retainers with a prosthetic maxillary lateral incisor were not included in the present analysis.

Case Scenario and Assumptions

The authors considered treatments that were performed on a healthy patient with unilateral agenesis of one maxillary lateral incisor in a healthy occlusion without any other dental problems (no other missing teeth, no crowns or partial dentures, no implants, no bone augmentation, etc), otherwise with balanced dental and skeletal relationships not requiring orthopedic or surgical treatment. Similarly, only patients with clear indications for the replacement of the missing maxillary lateral incisor were considered.

To develop the economic model for the evaluation of an ideal treatment, the following assumptions were made: all cases require an equal amount of orthodontic treatment where the costs are equal; orthodontic treatment outcomes for all cases are stable, and no relapse occurs after the removal of the fixed appliances; the orthodontic retention regimes all incur the same costs and same stability; in the case of implant placement or autotransplantation, the height and thickness of the alveolus is adequate; the patients retain their dentition over their lifetime; all treatment modalities provide the same health-related and oral health-related quality of life; all treatment modalities provide an equally esthetic outcome over the long term; all treatment modalities require the same amount and frequency of follow-up and maintenance.

Cost

Only direct costs were considered 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 clinical and laboratory costs were considered. For the FPD options, abutment tooth preparation was included. For the autotransplantation treatment option, reshaping and building up the transplanted tooth with the addition of composite resin to make it resemble a lateral incisor was also included.

The costs of the five different treatment modalities were calculated based on the national fee schedule in Switzerland, provided by the Swiss Dental Association, using a point scheme used by health insurances for reimbursement purposes. Costs were initially calculated in Swiss francs (CHF) and subsequently converted into international dollars. An international dollar is a hypothetical unit of currency that has the same purchasing power as the US dollar (USD) has in the United States. Costs in local currency units are converted to international dollars using Purchasing Power Parity (PPP) exchange rates. A PPP exchange rate is the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as the USD would buy in the United States. An international dollar is therefore used as a means of translating and comparing costs from one country to another using a common reference point, the USD. The PPP exchange rates used in the current study were developed by the World Health Organization.

Outcome

Meta-analyses or systematic reviews were used whenever possible to obtain the highest level of evidence with respect to the long-term outcome of individual treatments. All outcome data were based on the most recent literature available. The survival rate of each treatment modality was used as the primary

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outcome data. Survival, as used in dentistry for treatments such as implants and FPDs, is generally defined as functional retention without adverse clinical signs or symptoms. In this study, the 10-year survival rate of each treatment modality was desired as a long-term survival reference point.

Literature searches were undertaken in the following databases: PubMed, EMBASE, Scopus, Web of Science, CINAHL, and the Cochrane Library. The "related citations" function in PubMed was used to retrieve further articles. Authors' names that appeared on numerous occasions in the literature search were further searched to retrieve additional articles. The last search was conducted in January 2013. The search strategy included the following terms: *(1)* success, survival, outcome; *(2)* meta-analysis, systematic review; and *(3)* dental implant, tooth implant, single-tooth implant, implant-supported crown, bridge, fixed partial denture, resin-bonded bridge, resin-bonded fixed partial denture, cantilever bridge, cantilever fixed partial denture, conventional bridge, full-coverage fixed partial denture, autotransplantation, and tooth transplantation. Searches were conducted using a combination of one of the terms from each of the three search categories above. Wild-card characters (ie, autotransplant*) were also used. No language, publication date, or publication status restrictions were imposed. In the case of more than one meta-analysis or systematic review concerning the same treatment modality, the most up-to-date one was selected. The search and study selection was carried out independently by two reviewers. Any disagreement was resolved by discussion and consensus.

Cost-Effectiveness Analysis

The primary measure of effectiveness was the outcome (survival rate) of the individual treatment modality. The starting point of the cost-effectiveness strategy was a patient with a missing maxillary lateral incisor after orthodontic treatment to redistribute space for prosthodontic rehabilitation of the missing maxillary lateral incisor. The cost-effectiveness of the five treatment modalities in the current study was thus determined as the ratio of the survival probability of each individual treatment modality divided by the fee for that individual treatment in international dollars. Cost-effectiveness ratios were calculated to determine how the five treatment modalities rank.

Sensitivity Analysis

Cost-effectiveness in this study was dependent on the estimates of costs and survival rates. Costs may vary between different countries as well as within countries and between practitioners, and survival rate calculations may vary in different studies. Sensitivity analyses were necessary to allow for the possible variation in the order of cost-effectiveness treatment modalities, taking into consideration the variation in cost and survival estimates. This rerunning of the model with different starting parameters was essential to illustrate the impact that the inevitable inaccuracies may have on the overall model.

A one-way sensitivity analysis was carried out with one of the estimated variables changed. The range of survival rates obtained from the meta-analyses of individual treatment modalities was used for this purpose, and, in turn, variations in cost were also used, based on costs derived from different European countries, including one northern European country (the Netherlands), and one southern European country (Italy).

Results

Cost

The direct costs for the five different treatment modalities were calculated in CHF, based on the national fee schedule in Switzerland, and converted into international dollars using PPP exchange rates. The costs, in international dollars, were the following: single-tooth implant and implant-supported crown = 1,063.21 + 693.94; resin-bonded FPD = 1,189.51; cantilever FPD = 1,286.65; full-coverage FPD = 1,689.56; and autotransplantation = 852.94.

Outcome

The results of the literature search are shown in Fig 1. Four meta-analyses and one review were selected as the best evidence for the outcome of the different treatment modalities[13–17] (Table 1). For single-tooth implants and implant-supported crowns, resin-bonded FPDs, cantilever FPDs, and full-coverage FPDs, 10-year survival rates were extracted directly from the respective meta-analyses. For autotransplantation, neither a systematic review nor a meta-analysis was available, and thus the most recent review mentioning survival data from previous long-term survival studies was used. The mean survival rate was extracted from this review by calculating the average of the studies mentioned, weighting each study for sample size.

Cost-Effectiveness Analysis

Relative costs, survival rates, and cost-effectiveness values are depicted in Fig 2. The five different treatment modalities were ranked according to their

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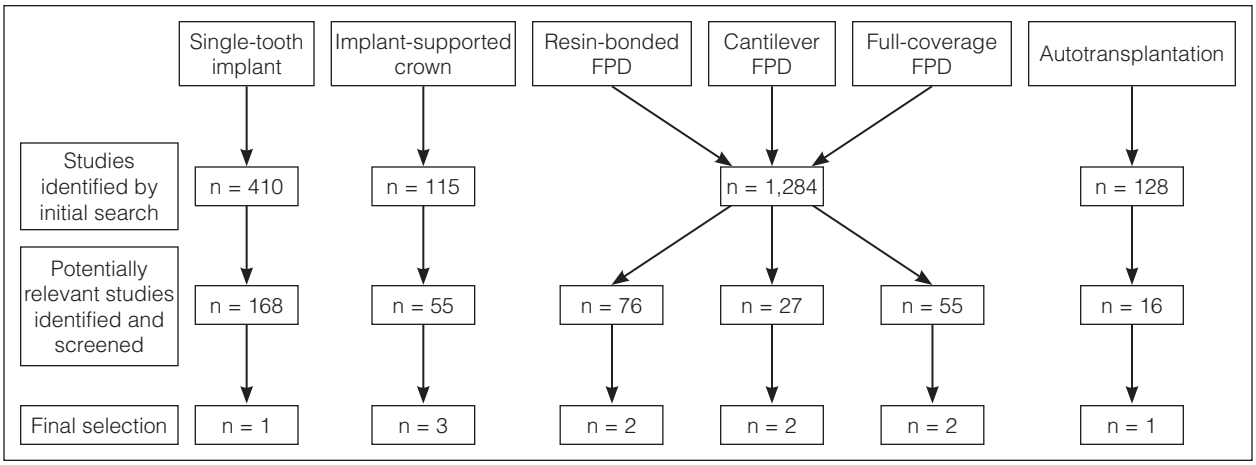

Fig 1 Flow diagram summarizing the literature search and article selection.

Table 1 Survival Rates for the Different Treatment Modalities

Treatment	Survival rate (%)	Reference
Single-tooth implant	95.2	Jung et al[14]
Single-tooth implant and implant-supported crown	89.4	Jung et al[14] Pjetursson et al[17] Pjetursson et al[15]
Resin-bonded FPD	65.0	Pjetursson et al[17] Pjetursson et al[16]
Cantilever FPD	80.3	Pjetursson et al[17] Pjetursson et al[15]
Full-coverage FPD	89.2	Pjetursson et al[17] Pjetursson et al[15]
Autotransplantation	94.1	Andreasen et al[13]

FPD = fixed partial denture.

Table 2 Cost-Effectiveness Values and Ranking for the Different Treatment Modalities

Treatment	Cost-effectiveness ratio	Ranking
Single-tooth implant and implant-supported crown	0.0529	4
Resin-bonded FPD	0.0546	3
Cantilever FPD	0.0624	2
Full-coverage FPD	0.0528	5
Autotransplantation	0.1103	1

FPD = fixed partial denture.

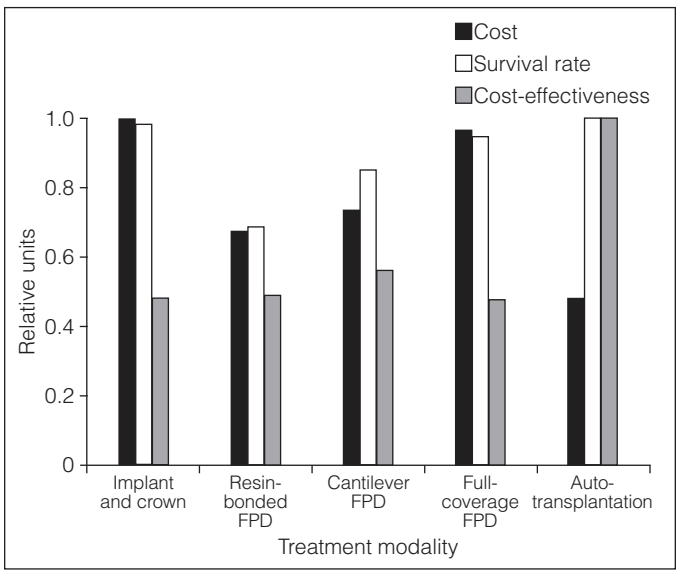

Fig 2 Relative costs, survival rates, and cost-effectiveness. Values are shown in relative units with the most costly treatment modality represented by a value of 1, the treatment modality with the highest survival rate represented by a value of 1, and the most cost-effective treatment modality represented by a value of 1).

cost-effectiveness ratio (Table 2). In calculating the cost-effectiveness for single-tooth implants and implant-supported crowns, the costs and survival rates of the single-tooth implants and those of the implant-supported crowns had to be considered. The ratio of the survival rate of each treatment (implant or crown) to the total cost (implant + crown) was calculated and the two were added together, weighting each cost-effectiveness in relation to the proportion of the total cost. The most cost-effective treatment modality was autotransplantation, whereas the least cost-effective was full-coverage FPDs.

Sensitivity Analysis

The costs of the five different treatment modalities were recalculated based on the national fee schedule in Italy, provided by the autonomous supplementary assistance fund of Italian journalists. Costs were initially calculated in Euros

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Table 3 Ranking Depending on the Cost Used for the Cost-Effectiveness Analysis (Sensitivity Analysis)

Treatment	Ranking (Swiss cost)	Ranking (Italian cost)	Ranking (Dutch cost)	Common ranking
Single-tooth implant and implant-supported crown	4	4	4	4
Resin-bonded FPD	3	2	3	–
Cantilever FPD	2	3	2	–
Full-coverage FPD	5	5	5	5
Autotransplantation	1	1	1	1

FPD = fixed partial denture.

(EUR) and subsequently converted into international dollars. The first (autotransplantation) and two last (single-tooth implant and implant-supported crown; full-coverage FPD) rankings remained unchanged, but the second and third rankings were opposite from what was found using Swiss costs (Table 3).

Similarly, the costs were again recalculated based on the Dutch national fee schedule, provided by the Dutch Dental Association. Costs were initially calculated in EUR, and subsequently converted into international dollars. Identical rankings were found as when using Italian costs (Table 3).

With the survival rates altered, obtained from individual studies mentioned in the meta-analyses, the rank of cost-effectiveness was recalculated. Rankings remained unchanged when the different survival rates found in the literature were used.

The present cost-effectiveness analysis was thus robust in identifying the most and two least cost-effective treatment modalities but not in evaluating the differences in cost-effectiveness between the other two treatment modalities.

Discussion

The present study provides the first comparative economic evaluation of different treatment modalities for the replacement of missing maxillary lateral incisors. In cases of unilateral maxillary lateral incisor agenesis with clinical indications to maintain the lateral incisor space, the most cost-effective long-term treatment modality for replacing the missing incisor was autotransplantation. The least cost-effective alternatives were single-tooth implants and full-coverage FPDs.

Single-tooth implants, despite their low cost-effectiveness, represent the most popular treatment alternative for the replacement of missing teeth.[4] The main benefit of this type of restoration is that the adjacent teeth remain untouched, contrary to the tooth-supported restorations available. This is particularly important in young patients with healthy unrestored dentitions. Implants in the maxillary anterior region, however, due to their osseointegration and lack of adaptation to eruptive and growth changes, do not follow the vertical eruption of the adjacent teeth. This may lead to infraocclusion of the implant-supported crown over time, even in mature adults,[18] which may compromise the esthetic rehabilitation of the missing tooth in this region. The good survival rates seen with implants may not be able to compensate for the increased cost of implant restorations, with regard to cost-effectiveness.

For tooth-supported restorations, the most conservative is the resin-bonded FPD, which leaves the adjacent teeth relatively untouched. The cost of these restorations is relatively less than other tooth-supported restorations, but the survival rate is also lower, with debonding being the most common cause of failure.[16] Occlusion, overbite, proclination of the abutment tooth, abutment tooth mobility, and bruxism are all factors that can dictate whether a resin-bonded FPD is an appropriate treatment modality for a particular patient.[4] Even with a good clinical indication, cost-effectiveness is questionable. Perhaps, however, the conservative nature of this treatment modality and the associated advantages of such an approach may make it suitable for many patients, despite its slightly diminished cost-effectiveness compared with the autotransplantation option.

Cantilever FPDs are more predictable and overcome the limitations of resin-bonded FPDs.[19] The canine, because of its root length and crown dimensions, is an ideal abutment for such restorations.[4] Moreover, when a partial-coverage preparation is used, this provides a more conservative approach to the tooth-supported restoration. The survival rate is much higher than for resin-bonded FPDs and the cost not much greater, making this treatment option relatively cost-effective.

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Conventional full-coverage FPDs are the least conservative and least cost-effective of all of the tooth-supported restoration treatment modalities and, therefore, are not ideal for replacing missing lateral incisors. The only clinical indication of choosing a full-coverage FPD over other treatment modalities is when the abutment teeth are already heavily restored or crowned. Reports show that teeth adjacent to implants are minimally affected by complications following implant placement, whereas teeth that had been prepared for abutments of FPDs or used as a retainer for a removable partial denture are exposed to higher risks.[20,21]

Previous attempts to evaluate the cost-effectiveness of treatments such as implants versus FPDs involved different case scenarios. The results of these previous studies essentially compared cost-effectiveness of implants to FPDs with inconclusive evidence. In a cost-effectiveness study comparing dental implants to prostheses in single-tooth replacement, the authors conclude that dental implants provide a more cost-effective treatment strategy.[22] Similarly, in another study, implants were found to be more cost-effective than FPDs.[23] Incici et al[24] calculated that the long-term cumulative treatment costs of restoring congenitally missing teeth with either restored FPDs or implant-supported crowns were equal. Scheuber et al,[25] in a meta-analysis, found similar costs and survival rate estimates when comparing implants to FPDs. The present analyses showed that single-tooth implants were more cost-effective with regard to long-term data when compared with conventional full-coverage FPDs.

Autotransplantation is the most cost-effective treatment for the replacement of a missing maxillary lateral incisor, according to the present analysis. It is, however, not a feasible treatment alternative in all cases. Patient selection in autotransplantation is of paramount importance, and interdisciplinary planning is important for a successful result.[26] This treatment approach should be considered either in patients where the correction of an existing malocclusion dictates premolar extraction, or where a sacrifice of a premolar solves a great functional and esthetic problem in the anterior region and creates only a minor problem at the donor site that can be corrected orthodontically.[13] Following autotransplantation, the transplanted premolar needs to be reshaped into a maxillary lateral incisor. For calculating costs in the present analysis, direct composite buildups were assumed. There are, nevertheless, some inherent limitations with direct composite buildups in the attempt to establish a normal incisor shape using a transplanted premolar due to the nature of the material and tooth shape.[26] Timing is also very important with this procedure being possible only in growing children, and the procedure is also technique sensitive requiring an experienced operator.[13,27]

Despite these possible drawbacks, some of the differences between an autotransplanted tooth and a single-tooth implant should not be neglected. An autotransplanted tooth is a natural biologic replacement with an adjustable position after surgery that erupts in synchrony with adjacent teeth and creates normal bone with a normal periodontal membrane and normal interdental gingival papillae.[26] On the other hand, an implant is an artificial replacement that osseointegrates and is thus ankylosed with no potential for positional change or eruption and often creates problems with regard to alveolar bone and interdental gingival status.[18]

This cost-effectiveness analysis was not able to identify differences between resin-bonded FPDs and cantilever FPDs, when considering the sensitivity of the model. This was more dependent on variations in cost as opposed to variations in survival rates. The relative costs of different treatment options vary widely from country to country and, thus, the absolute external validity of such a model in this regard is questionable. Sensitivity analysis, however, did demonstrate the robustness of this cost-effectiveness analysis in identifying the most cost-effective and two least cost-effective treatment modalities.

Conclusions

This cost-effectiveness analysis demonstrates that when replacing a missing maxillary lateral incisor, the most cost-effective treatment modality in the long term is autotransplantation, and the least cost-effective is a full-coverage FPD. However, when faced with a clinical situation in which lateral incisor replacement is indicated, other factors such as patient age, the state of the dentition, occlusion, and tooth conservation should have a bearing on the ultimate choice of restoration.

Acknowledgments

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Literature Abstract

Tobacco use and caries risk among adolescents: A longitudinal study in Sweden

The authors undertook a population survey of 10,068 adolescents 16 to 19 years of age. The caries status and tobacco use (cigarette smoking and use of smokeless tobacco) of this population was documented annually from 2006 to 2012. Results showed that the incidence of decayed, missing, and filled surfaces (DMFS) between users and nonusers of tobacco was significantly different (mean, 1.8 vs 1.2; proportion with the incidence of DMFS > 0, 54.2% vs 40.5%; $P < .0001$). Significant differences at the neighborhood level of the socioeconomic stratum were also observed. After controlling for baseline DMFS and sex, the incidence of DMFS was still significantly higher in the tobacco users compared to nonusers ($P < .0001$). The authors concluded that there is a clear association between tobacco use and increased caries development during adolescence. They also suggested that the findings shed light on the clinical caries risk assessment of tobacco-using adolescents and may be of value for community oral health planning.

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