Smoking Cessation Therapy is a Cost-Effective Intervention to Avoid Tooth Loss in Subjects With Periodontitis – An Economic Evaluation

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SMOKING CESSATION THERAPY IS A COST-EFFECTIVE INTERVENTION TO AVOID TOOTH LOSS IN SUBJECTS WITH PERIODONTITIS – AN ECONOMIC EVALUATION

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ABSTRACT

Background: Smokers present a higher prevalence and severity of periodontitis and, consequently, higher prevalence of tooth loss. Smoking cessation improves the response to periodontal treatment and reduces tooth loss. So, the aim of this study was evaluated the efficiency in resources allocation when implementing smoking cessation therapy vs. its non-implementation in smokers with periodontitis.

Methods: We adopted the Brazilian public system perspective to determine the incremental cost-effectiveness (cost per tooth loss avoided) and cost-utility (cost per oral-related quality-adjusted life-year ([QALY] gained) of implementing smoking cessation therapy. Base-case was defined as a 48 years-old male subject and horizon of 30 years. Effects and costs were combined in a decision analytic modeling framework to permit a quantitative approach aiming to estimate the value of the consequences of smoking cessation therapy adjusted for their probability of occurrence. Markov models were carried over annual cycles. Sensitivity analysis tested methodological assumptions.

Results: Implementation of smoking cessation therapy had an average incremental cost of U$60.58 per tooth loss avoided and U$4.55 per oral related-QALY gained. Considering uncertainties, the therapy could be cost-effective in the most part of simulated cases, even being cheaper and more effective in 53% of cases in which the oral-health related outcome is used as effect. Considering a willingness-to-pay of US$100 per health effect, smoking cessation therapy was cost-effective, respectively, in 81% and 100% of cases in cost-utility and cost-effectiveness analyses.

Conclusions: Implementation of smoking cessation therapy may be cost-effective, considering the avoidance of tooth loss and oral health-related consequences to patients.

Keywords: Cigarette Smoking; Smoking Cessation; Periodontitis; Health Economics, Modelling

BACKGROUND

Cigarette smoking is a global public health problem associated with high morbidity and mortality [1]. It is a major risk factor for health problems, such as cancer, cardiovascular and respiratory diseases. Besides, smoking is a risk factor for oral diseases, such as oral cancer, periodontitis, gingival recession, tooth loss and implant failure [2-4]. Smoking is also associated with higher costs in periodontal treatment [5-7] and increases the cost of life-time periodontal treatment from 8.8% up to 71.4% [7].

There is overwhelming evidence about the benefits of smoking cessation to the general health [8, 9]. Quitting smoking also improves oral health conditions [4] . Two interventional studies observed greater probing depth reduction and clinical attachment gain in periodontitis patients that quit smoking, when compared to non-quitters [10, 11]. Moreover, observational studies have shown that former smokers lose fewer teeth than current smokers [12, 13]. Therefore, smoking cessation therapy (SCT) should be considered an important component of periodontal treatment [14].

Medical literature demonstrated that SCT is cost-effective because it reduces health care expenditures associated with health effects of smoking [15, 16]. Although there are some economic evaluations of periodontal [17-20], so far, this is the first study that evaluated the cost-effectiveness of implementation of smoking cessation therapy for periodontitis patients. Our hypothesis was that SCT could be a cost-effective intervention because it reduces the risk of tooth loss and, consequently, it reduces the costs associated with therapies aimed to replace teeth (prosthesis and implants). Such appraisal could be extremely relevant in decision-making since smoking cessation therapy is available in the Brazilian public health system (PHS), but is underused by dentists. Therefore, the aim of this study was to evaluate the efficiency in resources allocation when implementing smoking cessation therapy (SCT) vs. its non-implementation in smokers with periodontitis that received periodontal treatment to prevent tooth loss, in the context of the Brazilian PHS.

METHODS

This economic evaluation has been prepared according to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [21].

Setting and Model

This study describes a decision analytic model considering a male Brazilian subject, age of 48 years-old and life expectancy of 28 years [22] as the base-case. In this model, subjects are tobacco smokers with high level of dependence (>10 cigarettes per day), with 20 teeth and generalized periodontitis stage III, grade C [23, 24]. Age and number of remaining teeth were based on a previous study from our group, which evaluated the effect of smoking cessation in periodontitis patients in a reference center for smoking cessation in Brazil [25].

The study was conducted from the Brazilian PHS perspective. Data was modeled using a Markov simulation model. Tree Age Pro 2017 (TreeAge Software, Williamstown, MA, USA) was used for data modeling and analysis.

Comparators

A decision analytic modeling framework was constructed to estimate the efficiency in resource allocation when implementing SCT in smoker patients with periodontitis that received periodontal treatment to prevent tooth loss. This structure was used to permit a quantitative approach to that would estimate the value of the consequences of SCT adjusted for their probability of occurrence (Supplementary file 1).

Subjects entering the model were smokers with periodontitis. Some subjects were supposed to receive SCT and others not. In both cases, they could stop smoking or not. All subjects received non-surgical periodontal treatment (six sessions of scaling and root planning) and one session of maintenance therapy (one session of scaling and root planning). In the decision-analytic modeling framework, this stage was represented as a simple decision tree. No possibility of relapsing smoking and/or need of reintervention with SCT was considered.

In the Markov models, at each cycle, we considered that patients could transit among possible health statuses. Thus, after initial treatment, at the end of each year (cycle), subjects with periodontitis could transit between three states: 1) to stay in maintenance therapy with no tooth loss, 2) to lose a tooth and not receive rehabilitation or 3) to lose a tooth and receive prosthesis rehabilitation. When a tooth loss occurred, we assumed that the remaining teeth would continue to receive periodontal maintenance therapy (Figure 1; Supplementary File 1). As in a previous paper [7], we assumed that current smokers would require two extra sessions of maintenance therapy. Further, we assumed that quitters would present better response to periodontal therapy [25]. To avoid clustering effect, only one tooth per patient was simulated.

Time Horizon

The life expectancy of a 48 years-old Brazilian male is 28 years [22]. Therefore, the time horizon of the analysis was set at 30 years.

Discount rate

In order to adjust time preference, costs and benefits were adjusted. A discount rate of 5% for costs was considered in this model in accordance with Brazilian guidelines [26].

Modeled parameters

Transition probabilities were defined by data from previous published studies. Since we used annual cycles in the model, if a previous published study used a different time frame (e.g., 10 years), we converted this probability in a 1-year value (Table 1)

The probabilities of quitting smoking with SCT after one year were based in a study conducted in Brazil that found a probability of 30% of cessation after one year [27]. The probability of quitting smoking without any therapy was 7% [28].

Probability of tooth loss during maintenance therapy was calculated using risk ratios of tooth loss in current and former smokers, according to the expression below:

$$p = RR_{\text{tooth loss}}^{*} \text{ X } p_{\text{tooth loss non-smokers}}$$

In our model, when the tooth was lost, the subject could receive rehabilitation with partial prosthesis or could not receive any rehabilitation. This probability was based on a population-based survey about dental conditions of the State of São Paulo, Brazil [29].

Health Effects

Cost-effectiveness analysis (CEA) was conducted considering the presence of the tooth (maintenance therapy) as treatment success and tooth loss as failure, regardless of prosthetic rehabilitation or not.

Cost-utility analysis (CUA) was performed combining utility values with time spent in state of health, resulting in number of quality-adjusted life years (QALY) [30]. Determination of the utilities was conducted through a conversion of Oral Health Impact Profile (OHIP) scores [31, 32]. OHIP scores, selected from studies with Brazilian subjects, were converted to a continuous value from 0 to 1 (0: lowest score corresponding to the worst oral health state imaginable; 1: highest score corresponding to the best oral health state imaginable). We assumed a linear relationship between OHIP scores and the oral-health related utility scores obtained. Utility scores with corresponding OHIP score and data source are shown in Supplementary File 02.

Outcomes

Incremental costs (∆cost) and incremental effects (∆effect) were calculated based on the fact that incremental cost per health effect could be estimated to determine the differences both in costs and in the effects of implementation of SCT, over non-implementation.

Costs and Resources

We used costs from the Brazilian public service. We considered only direct costs of the procedures (Table 2) and the need of one cycle of SCT. Possible relapses and need of repetition of SCT were not explored in this study.

SCT adopted in the Brazilian public health system consists in cognitive-behavioral therapy, nicotine replacement therapy (transdermal patches 7, 14 or 21mg and gums 2 or 4mg) and bupropion hydrochloride 150mg. Brief counseling is conducted during the routine consultations. The therapy is conducted by doctors, nurses and psychologists, in specialized centers. Brazilian SCT model consists in four weekly sessions in the first month and 12 sessions until the completion of one year of treatment. Direct costs were based on a trial conducted in Brazil [33]. Costs with professional training for SCT were not considered in the primary model, but they were modeled in the sensitivity analysis. In the Brazilian public service, periodontal treatment, maintenance therapy and prosthetic rehabilitation are conducted in Dental Specialty Centers (CEOs). We chose partial removable prosthesis as the type of prosthetic rehabilitation in our model because partial fixed prosthesis is not performed in the Brazilian PHS. Moreover, the option for implant therapy was modeled in the sensitivity analysis. This therapy is performed only in some CEOs, in some Brazilian cities, and in a reduced number when compared with partial removable prosthesis.

Costs of periodontal procedures, prosthetic rehabilitation and implant therapy were calculated considering the hourly wages of the dentist in Dental Specialty Centers (CEOs) [34], PHS unified table and medications costs (BPS- Health Price Bank) [35].

All costs from years prior to 2020 were adjusted for inflation using the National Consumer Price (https://www.bcb.gov.br/acessoinformacao/calculadoradocidadao). The conversion into purchasing power parity (ppp) was based on The International Monetary Fund considering 1.00 US dollar as R$ 2.46 ("https://www.imf.org/external/datamapper/PPPEX@WEO/OEMDC/ADVEC/WEO WORLD).

Sensitivity analysis

Deterministic and probabilistic sensitivity analyses were conducted considering the figures shown on Table 3. Time horizon and model settings were kept constant.

Deterministic Sensitivity Analysis

We varied SCT costs to cover different scenarios, such as different protocols. The costs used in this analysis were based on the costs presented by Mendes et al. (2016) [33]. Professional's training was considered in a separate analysis as a global cost for SCT program maintenance (Table 3).

The projected costs of the items of periodontal treatment, maintenance therapy and no rehabilitation were varied in 10%.

Discount rate was analyzed ranging from 3% to 7%. Probability of annual tooth loss in non-smokers varied between probabilities from studies with Brazilian subjects [36, 37]. Probability of losing a tooth and not receiving rehabilitation varied, with the insertion of a higher probability of any rehabilitation [38].

To observe the influence of the rehabilitation with implant therapy, the cost and utility of this therapy were inserted in the model in the condition of subjects that lose a tooth and received rehabilitation (Table 02).

Utility scores varied using the standard deviation of the mean scores.

Probabilistic Sensitivity Analysis

Distribution of variables that could interfere in the model and their respective distributions were inserted in the probabilistic sensitivity analysis (Table 3). Monte Carlo simulations repeated 1000 times were plotted on the cost-effectiveness plane for both analysis (CEA and CUA).

Probability of tooth loss in smokers and non-smokers varied using the natural logarithm of the confidence intervals (CI) of the risk ratios of tooth loss in former and current smokers.

Probability of losing a tooth and not receiving rehabilitation varied between the average of CI of this probability.

Analysis of uncertainty and Cost-Acceptability curves

All stochastic model input parameters were expressed using probability distributions derived primarily from the selected studies (Table 1). Modeling assumptions were varied through a series of deterministic sensitivity analyses on the probabilistic model. The assumed probability distributions used for each stochastic model input parameter are presented in Table 3. Normal distributions were assumed for risk of tooth loss, triangular distributions were used for cost and utility variables and uniform distribution was used in the discount rate.

In probabilistic analysis, we used Monte Carlo simulation techniques with 1,000 trials for each separate run of the model. Average costs, effects, cost-effectiveness, and cost-utility results were based on means of the simulated results. These results were plotted in a cost-effectiveness plane, presenting information on the joint distribution of incremental cost and incremental effectiveness. Therefore, probabilities of combing outcomes (risks and benefits) in different quadrants could be explored.

In Brazilian guidelines for health technology assessments, there is not a threshold to determine whether an intervention is cost-effective or not. Additionally, we considered health effects whose potential willingness to pay (WTP) were not known. This is the reason why Cost-Effectiveness Acceptability Curves (CEAC) were plotted supposing different hypothetical values for WTP thresholds.

RESULTS

Incremental Costs and Effects

In both analyses, when the base-case was assumed, implementation of smoking cessation therapy was dominant (less costly and more effective) over non-implementation (Table 4). Implementing the therapy saved approximately US$ 100 over the time horizon accompanied by slight better effect, both in CEA and CUA.

Sensitivity analyses and characterization of uncertainty

The majority of the parameters tested in sensitivity analyses did not impact on the results and smoking cessation therapies remained a cost-effective option despite varying some model assumptions. When the cost of SCT was varied to cover different scenarios, implementation of the therapy was also not dominant over non-implementation for some of them (Figure 2). For the maximum scenario, expenses for implementing SCT were observed (Δcost=U$201). In this case, incremental costs of US$ 403 per tooth loss avoided and US$ 347 per oral-QALY gained were calculated.

Importantly, even when implant therapy was used to rehabilitate patients with tooth loss, implementation of SCT remained cost-effective and non-implementation of SCT was dominated by the implementation. Other assumptions did not influence on previous trends.

When considering the uncertainties, implementation of SCT tended to be more costly and more effective in the great majority of the simulated cases to the CEA (99.9%). In the CUA, 53% of the simulated cases were in the dominant quadrant (Figure 2). Besides, approximately 53% of the cases would be in the northeast quadrant, being maximum incremental cost as high as approximately US$300 associated to incremental oral-related QALY gained ranging from 0 to 2.5 (Figure 2 and Supplementary file 3)

CEACs demonstrated that SCT implementation, at a hypothetical WTP of US$ 100, is considered as the optimal strategy in 100% of cases, when concerning to tooth loss (Figure 3). When QALYs were considered for the analyses, at the same hypothetical WTP, 81% of the iterations were cost-effective (Figure 3). Considering the last situation, 98% of cost-effective iterations were observed at a WTP=US$500.

DISCUSSION

The results of this study show that implementation of SCT is an efficient way of allocating resources compared to its non-implementation, in the perspective of the Brazilian PHS. Even considering additional costs related to cognitive-behavioral intervention for smoking cessation, they tended to be favorably balanced by the health gain achieved. In some circumstances, the initial extra expenses in implementing the SCT may either be compensated by costs saved in the subsequent dental treatment for smokers.

We chose the PHS perspective because all Brazilian citizens are entitled to the services provided by the public system [39]. Currently, SCT in the PHS is conducted by a multi-professional team that does not include dentists. However, this intervention could be delivered by dentists in the Brazilian PHS [40], especially if one considers that SCT conducted by oral health professionals increases tobacco abstinence rates [41].

The cost-effectiveness of smoking on periodontal therapy in private practice was evaluated by Fardal et al. (2018) [7], based on costs of the American Dental Association. They found an increased cost of periodontal treatment for smokers and that the lifetime cost of periodontal therapy is equivalent to about 25% of the cost of smoking for patients who smoke 20 cigarettes per day. However, the cost-effectiveness of SCT was not evaluated. Feldman et al. (2019) [42] compared the cost-effectiveness of a high-intensity therapy with a low-intensity smoking cessation intervention in a Swedish dental setting. Their results favored the high-intensity smoking cessation intervention when willingness to pay was €4000/QALY. The utility weights derived via general health-related quality of life questionnaire. Their results are important because this high-intensity smoking cessation intervention is very similar to SCT adopted in Brazilian PHS. According to their findings and our results, SCT is a cost-effective intervention for periodontitis patients, which empathizes the necessity to increase application of SCT in the Brazilian PHS dental setting. SCT is can be performed by dentists and it is currently underused in Brazil.

From the Brazilian PHS perspective, SCT could be considered a cost-effective option (probability from 81-99% excluding the uncertainties) even considering a low WTP threshold (US$). Even when uncertainties are considered, we could observe that a low incremental cost (not exceeding US$300) could be expected. As for the health effects considered as outcomes in the present evaluations, we do not have a known WTP. We analyzed the CEA and the probabilities of simulated cases yield on different quadrants as a manner of permitting the decision-maker to judge this information and consider if it is acceptable. It is possible to opt for the different preferences for inefficiencies occurring in different quadrants since both size and nature of risks may be presented [43].

Although in both analysis, CEA and CUA, the implementation of SCT was cost-effective, the health effects in CUA were smaller than in CEA. This result was expected because effects in subjective measures are less evident than in objective measures.

We chose tooth loss as the outcome of CEA because it is considered the true endpoint of periodontal disease [44, 45]. It is the most important objective outcome to the patient and therefore it might be considered the most appropriate outcome in an economic analysis [30]. Some of the published studies used surrogate outcomes, such as bleeding on probing, plaque index, probing depth reduction and clinical attachment gain [46 – 48]. However, the precise impact of these surrogate outcomes on the patient is unclear [30].

We included a CUA in our study, because this type of analysis allows including a measure of the patients' preferences and perception about their health. The importance of patient related outcomes is impacting in more studies with CUA in dentistry [49]. However, there is still a scarcity of this type of analysis in some regions, such as in South American countries [49]. Medical literature usually uses EuroQOL-5Dimension (EQ-5D) [50] or Structured Form 6 Dimension (SF-6D) [51] to determinate QALY. However, these instruments evaluate general health, which is unlikely to be sensitive to important domains of oral health, such as chewing ability or aesthetics [52]. In the absence of a suitable measure in Dentistry, and considering the low sensitivity of medical questionnaires, we assumed that the utility was proportional to quality of life. This methodology was proposed by previous studies that converted scores from quality of life questionnaires to utilities scores between 0 and 1 and reflected changes related to periodontal conditions/treatment [53, 54]. Even though this is not the ideal approach, the use of this interim tool allowed the incorporation of a patient-centered approach into the analysis. We believe that these limitations do not impact on our findings because the utility scores were used in both strategies that were analyzed.

The inclusion of CUA also allows verifying that there are situations in which SCT could be cost-saving compared to its non-implementation, what is an additional argument to endorse this therapy in the PHS. On the other hand, our CUA should be carefully interpreted, because it is not possible to affirm that quality of life has a linear relationship with utility. We expect that the use oral health-related quality of life instruments may have registered oral health conditions that are be important to the patient, which are not necessarily comparable to general health status. On the other hand, the implicit limitations under this interim assumption should be considered when comparing to QALYs reported in other studies for making decisions based on that. Oral health-specific utility measures will be more sensitive in capturing the effectiveness of oral health interventions [49]. Instruments that use an indexed scale for oral health-related aspects need to be developed in order to improve the comparison between studies and different therapies.

We applied sensitivity analysis to characterize the uncertainty of our results. We tested a model with implants because this type of rehabilitation presents better utility scores than partial prosthesis, but it also includes higher costs in the model. However, even considering these higher costs, rehabilitation with implants did not affect the results and the implementation of SCT remained a cost-effective therapy. Further, it was dominant over the non-implementation of SCT. Partial fixed prostheses were not tested in our models since they are not available in the Brazilian PHS. Moreover, they may result in additional harms such as pulp exposure, which may lead to endodontic treatment [19].

Different scenarios, considering differential use of resources in SCT [33] were considered when the SCT costs were varied in sensitivity analysis. A marginal dominance was observed, since when varying the SCT costs, the therapy remained cost-effective (but not dominant, as in the base-case). These findings also provide evidence that SCT should be implemented for PHS. Since the cognitive-behavioral therapy is responsible for the majority of the SCT costs, we believe the variation in SCT costs considering these different scenarios may also reflect possible variations proposed in different protocols for SCT, even those different from Brazil. Although the costs for professional training were not included in the primary model, even under a conservative approach, considering the implementation of a new strategy in the PHS, these additional costs did not impact on present results.

The number of sessions of cognitive-behavioral therapy in SCT seems to exert the same influence on cost-effectiveness of the therapy. The number and frequency of periodontal maintenance sessions can vary according to clinical conditions, such as extension and severity of the disease. The number of SCT sessions was fixed, as in the Brazilian protocol for SCT, but different scenarios were used in the sensitivity analyses to explore these possible variations. Even when we tested variations in SCT costs, the implementation of SCT remained cost-effective. Therefore, despite exploring possible variables and uncertainties related to our models for CEA and CUA, we reinforce that the SCT may be a cost-effective therapy for periodontitis patients to be implemented in the Brazilian PHS.

Economic evaluations are a standard tool in the assessment of health care technologies in order to maximize benefits from the available resources [55]. The need to allocate public finances increased the interest in cost-effectiveness research in dentistry [56]. A cost-effectiveness criterion can play an important role by guiding the incorporation of new technologies into the population. Policymakers from some countries, such as Australia, Canada and European countries, have adopted economic evaluations to their drug guidelines and reimbursement [57]. The present findings are especially important for the Brazilian PHS and demonstrate that SCT should be implemented. It is necessary to emphasize that studies with different populations, costs and perspectives should be conducted to confirm the cost-effectiveness of the implementation of SCT in relation to tooth loss in different scenarios. This model can be used as a model to future cost-effectiveness analysis with costs and effects from other countries. As we adopted a model in which repetitions of SCT were not included due to smoking relapse, other models may also test the influence of variables related to that in the cost-effectiveness of SCT.

CONCLUSIONS

Implementation of SCT in periodontitis patients from the Brazilian public health system (PHS) is a more efficient way of allocating resources compared to its non-implementation, possibly to be cost-saving in some circumstances both when considering tooth loss or oral health-related QALY gains.

Abbreviations

SCT: smoking cessation therapy; CHEERS: Consolidated Health Economic Evaluation Reporting Standards; PHS: Brazilian public health system; CEA: cost-effectiveness analysis; CUA: cost-utility analysis; QALY: quality-adjusted life years; OHIP: Oral Health Impact Profile; CEOs: Dental Specialty Centers; ppp: purchasing power parity; WTP: potential willingness to pay; CEAC: Cost-Effectiveness Acceptability Curves

DECLARATIONS

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None.

Availability of data and materials

All data generated or analyzed during this study are included within the article (and its additional files).

Authors' contribution

MLSS: formulated the decision tree and bubble diagram, collected probabilities used in the Markov model, collected costs, elaborated tables, wrote the manuscript and submitted the manuscript; FCAC: collected PHS costs and contributed to write the manuscript; MMB: performed the economic analysis, contributed to formulate the decision tree and bubble diagram, elaborated figures and contributed to write the manuscript; CMP: contributed to formulate the decision tree and bubble diagram, contributed to write the final version of the manuscript. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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TABLES

They were submitted as individual files.

Table 1: States and Probabilities used in the model

Table 2: Cost survey on several states

Table 3: States and Probabilities used in Sensitivity Analysis

Table 4: Incremental costs and effects for implementation of SCT over the non-implementation of SCT

FIGURE LEGENDS

Figure 1: Bubble diagram: states and transitions used in the model

Figure 2: Cost-effectiveness planes considering as health effects (a) the avoidance or prevention of tooth loss and (b) the oral-related quality-adjusted life-years. ($P_{quadrant:}$ probability of simulated points is found on that quadrant – NE: Northest, NW: Northwest, SE: Southest; SW: southwest, PSA: Probabilistic Simulation Analysis).

Figure 3: Acceptability curves considering as health effects (a) the avoidance or prevention of tooth loss and (b) the oral-related quality-adjusted life-years.

SUPPLEMENTARY FILES

Supplementary file 1: Decision tree

Supplementary file 2: Utility scores

Supplementary file 3: Expected costs, outcomes, cost-effectiveness, cost-utility based on deterministic model by varying each variable from a minimum (green) to a maximum (red) values

Figures

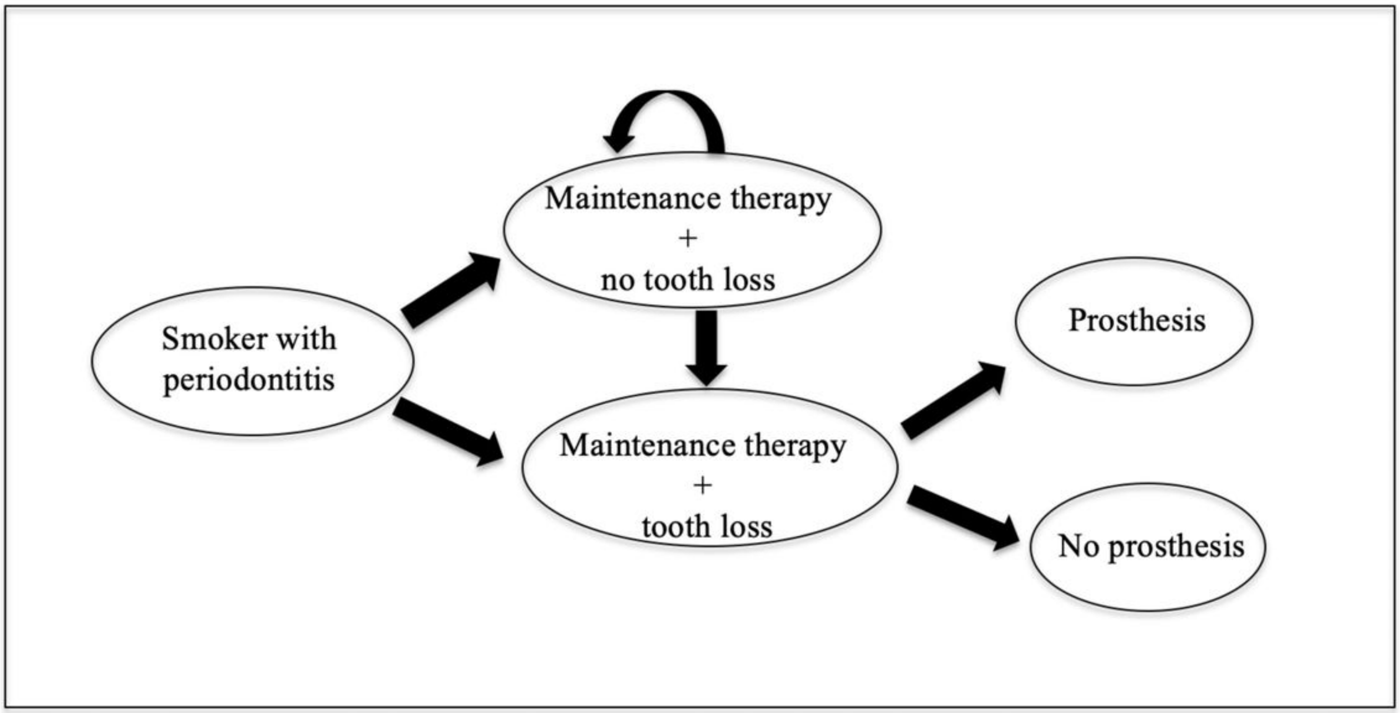

Figure 1

Bubble diagram: states and transitions used in the model

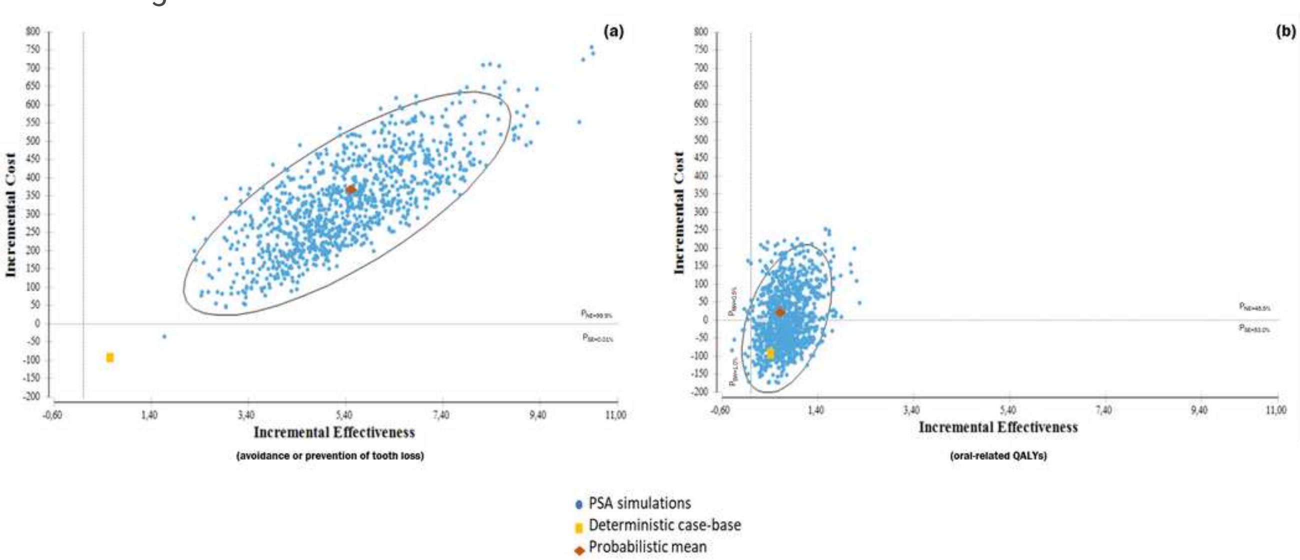

Figure 2

Cost-effectiveness planes considering as health effects (a) the avoidance or prevention of tooth loss and (b) the oral-related quality-adjusted life-years. (Pquadrant: probability of simulated points is found on that quadrant – NE: Northest, NW: Northwest, SE: Southest; SW: southwest, PSA: Probabilistic Simulation Analysis).

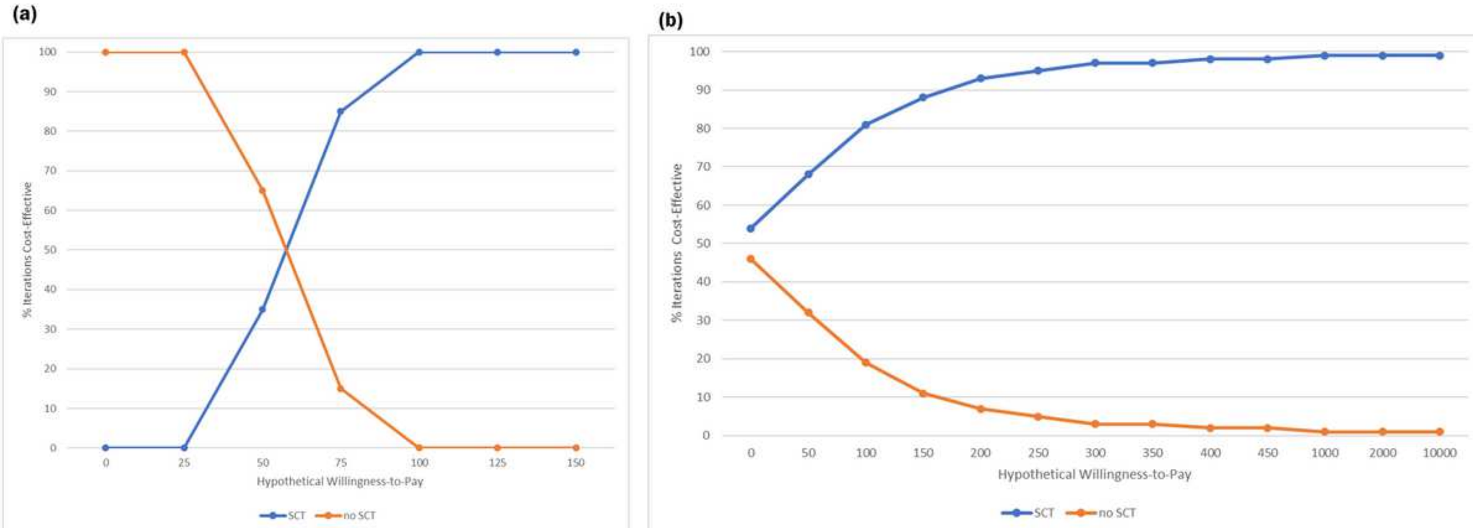

Figure 3

Acceptability curves considering as health effects (a) the avoidance or prevention of tooth loss and (b) the oral-related quality-adjusted life-years.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplementaryfile1.pdf
- Supplementaryfile02.docx
- SuplememntaryFile03.docx