

Adding smoking to the Fardal model of cost-effectiveness for the life-time treatment of periodontal diseases.

Øystein Fardal PhD * †‡

Jostein Grytten PhD ‡

John Martin §

Stig Ellingsen ||

Patrick Fardal *

Peter Heasman PhD ¶

Gerard J Linden PhD #

* Private practice, Egersund, Norway,

† Institute of Education for Medical and Dental Sciences

University of Aberdeen, Aberdeen, UK

‡ Institute of Community Dentistry, University of Oslo, Norway

§ Private practice, State College, PA and PreViser Corporation,

Concord, NH. USA.

|| Department of Periodontics, University of Oslo, Norway

¶ School of Dental Sciences, Newcastle University, Newcastle upon Tyne, UK

Centre for Public Health, School of Medicine Dentistry and Biomedical Science,

Queen's University Belfast, UK

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Address for correspondence: Øystein Fardal, Johan Feyersgt. 12, N-4370 Egersund,

Norway

Telephone 51491555

email: fardal@odont.uio.no

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Running title: Smoking cost and periodontal treatment

Summary of key findings: Smoking adds extra financial and human costs to the life-time cost of periodontal therapy.

Background

Little is known about the financial and human costs that smoking adds to the life-time treatment of periodontal disease.

Materials/Methods

The total life-time cost of periodontal treatment was modelled using data from private periodontal practice. The costs of initial and supportive therapy, re-treatment and tooth replacements (with bridgework or implants) were identified using average dental charges from the American Dental Association survey. Smoking costs at \$6 and \$10 for 20 cigarettes were compared to the costs of life-time periodontal treatment for stable, unstable and non-responsive compliant patients.

Results HERE

Smoking added 8.8% to the financial cost of the life-time cost of periodontal therapy in stable maintenance patients, 48.4% in patients who needed extra maintenance care and 411.2% in non-responding patients. The cost of smoking far exceeded the cost of periodontal treatment; For patients who smoked 10 to 40 cigarettes per day at the cost of \$6 or \$10 a pack, the cost of smoking exceeded the cost of life-time periodontal treatment by between 2.7 and 17.9 times. Smoking 40 cigarettes at \$10 a packet for 3.4 years would pay for the entire life-time cost of periodontal treatment. The extra life-time cumulative human cost may reach 50% but is difficult to assess accurately.

Conclusion

Smoking adds extra financial and human costs to the life-time treatment of periodontal disease. The cost of smoking itself dwarfs the cost of periodontal therapy.

Key words: Periodontal disease, treatment costs, cigarette smoking, cost effectiveness

Introduction

The financial and human cost caused by smoking to individuals, their families and society has been the focus of attention for many years. However, little is known about the specific extra cost of smoking associated with periodontal disease and the treatment of this disease.

Epidemiological studies implicate smoking as a risk factor for periodontal disease with consistent results across studies showing both a strong association with a dose response, a temporal sequence of smoking and periodontal disease as well as biologic plausibility¹. The possible mechanisms explaining the association between smoking and periodontal diseases have been reviewed in several excellent articles²⁻⁵.

The ultimate long-term outcome measure of periodontitis is tooth loss. In this context, a large study of 23376 participants found a two to three times higher rate of tooth loss in smokers compared with non-smokers⁶. Similar findings were also reported for stable long-term maintenance patients in a specialist periodontal practice⁷. From the same practice setting it was also shown that refractory patients who were heavy smokers had a 35 times higher rate of tooth loss than non-smoking stable periodontal patients⁸. In addition, these refractory patients had a higher rate of implant complications when lost teeth were replaced with implants. A systematic review reported a 36% higher level of peri-implantitis in smokers than in non-smokers⁹. The poorer response to periodontal therapy in smokers¹⁰⁻¹² means that more treatment and the replacement of an increased number of teeth lost due to progressive periodontitis will be required for the life-time maintenance of the dentition.

The Fardal model was developed to assess the life-time cost and the cost-effectiveness of periodontal treatment in private practice settings¹³. Subsequently, risk and severity were added to this model¹⁴. The original model showed that patients who chose not to have periodontal therapy could replace only four teeth or less with implants or bridges before this approach would exceed the direct cost of life-time periodontal treatment¹³. Patients who had initial periodontal therapy but did not subsequently comply with maintenance therapy could replace three teeth or less. It is not known how smoking affects this cost calculation. Patients and clinicians have so far not been able to calculate the specific extra cost caused by smoking on the outcome of the periodontal treatment. A simple model to explain this extra cost would be useful and might encourage smoking cessation. This is particularly pertinent, as it has been shown that a number of periodontal parameters revert to normal when smoking stops¹⁵.

We hypothesise that smoking adds considerable extra financial and human cost to the life long treatment of periodontal disease. The aims of this study are:

- I. To calculate the direct cost of smoking by applying the results from a long-term tooth loss study⁷ to the life-time cost and cost-effectiveness models^{13,14} including the cost of cigarettes, tooth replacements and also incorporating a dosage relationship.
- II. To make cost projections based on the effects of smoking in relation to the various types of tooth replacements.

Materials and Methods

Calculations of the total life cost of periodontal treatment were made using the model

proposed by Fardal et al. (2012)¹³. Cost calculations for periodontal therapy were based on patients who first attended a specialist practice between 1986 and 1998⁷. The data from this population were used to calculate the costs of periodontal therapy over the lifetime for the average patient^{7,8,13,16-21}.

One hundred patients (62 females and 38 males) were observed for 10 years. The patients were interviewed about their smoking habits in terms of the numbers of cigarettes smoked per day. The average age of patients at the initial examination was 46.6 years and the average length of the initial periodontal therapy was 12 months. Life expectancy in the United States in 2015 was 78.8 years²². Calculations were based on an average of 31.2 years of supportive periodontal therapy (SPT) after the completion of initial periodontal treatment for each patient. Average values of fees from the American Dental Association survey from 2015 were used²³. Sensitivity assessments at 10% higher and 10% lower fees were also carried out. The values were discounted over 32.2 years at 3%.

Initial periodontal treatment (IT)

Average cost was calculated for each patient based on an initial examination including radiographs, four sessions of periodontal scaling including oral hygiene instructions and 4.5 sessions of periodontal surgery with post-operative appointments¹³. Due to the wide variety in the types of periodontal surgery in the ADA survey, a standard surgical fee of \$ 1100 was used.

Supportive periodontal therapy (SPT)

Cost was calculated for 2 visits for SPT per year over 31.2 years at a cost of \$146 for each session. The practice is modelled on a shared maintenance therapy with the referring

dentist. However, the visits to the referring dentist also include caries control and other non-periodontal therapies, so the costs of these were not included in the calculations.

Re-treatment (RT)

Fardal & Linden¹⁸ showed that 50% of patients required surgical re-treatment, over and above regular SPT. Patients who required re-treatment received this on average 6.7 years after initial therapy. The average cost per surgical re-treatment session was \$1100. The total number of sessions for those who required re-treatment was calculated at 4.7 (31.2 / 6.7 years).

Tooth loss and tooth replacement (TR)

Fardal et al.⁷ showed that a group of 100 patients lost 36 teeth over a 10-year period (0.036 teeth per patient per year) even when initial periodontal treatment was followed by strict compliance with maintenance therapy. In the patient group 26 smokers lost 15 teeth which equated to 0.058 teeth / patient / year, while 74 non-smokers lost 21 teeth (0.028 teeth/ patient /year). This was extrapolated over the 32.2-year SPT and it was assumed that the rate of tooth loss remained constant. It was estimated that each smoker and non-smoker would lose on average 2.0 teeth and 0.96 teeth respectively. As 44% of the lost teeth were identified as second molars⁷ it was assumed for the present study that none of these would be replaced. The total number of teeth which would need to be replaced was calculated as 1.12 (56% of 2.00) for smokers and 0.54 (56% of 0.96) for non-smokers.

For the purpose of this study it was decided that all teeth that were lost would be replaced with either bridgework or implants. To calculate the cost of replacing a tooth, the price for a bridge or an implant was taken as \$3500. The average fees from the ADA survey showed

a fee for a three unit bridge of \$3405 and an implant supported tooth replacement at \$3626. Since there was considerable variations making up these average fees and to avoid calculating all scenarios with both three unit bridges and implant replacements a common fee for both was used for this study.

Stable non-smokers formed the reference group against which comparisons were made:

Scenario 1. Extra cost incurred by smoking for stable maintenance patients.

Scenario 2: Extra cost incurred by smoking for unstable maintenance patients.

As the damaging effects of smoking relate to the progressive loss of periodontal attachment, some smokers may be clinically unstable and require added maintenance care and re-treatment to reduce further tooth loss. The extra cost of one extra maintenance visit per year (50% increase) as well as a 50% increase in re-treatment was examined.

Scenario 3: Extra cost incurred by heavy smoking for non-responding patients (NR)

From the same practice setting⁸ it was reported that 2.2 % of the patient population were non-responsive to treatment and had a 35 times higher rate of tooth loss than stable periodontal patients. Multiple regression analysis showed that heavy smoking (>20 cig/day), family history of periodontal disease and stress was associated with being in the NR group. Projected tooth loss was 26.8 teeth per patient. The tooth loss distribution was different for these patients than the stable population as only 7.5% of teeth lost were second and third molars. Replacements were therefore calculated as: $26.8 * 92.5\% = 24.8$. The extra cost of one extra maintenance visit per year (50% increase) as well as a 50% increase in re-treatment to reduce tooth loss was also examined in these patients.

Cost of cigarettes

The cost of a pack of 20 cigarettes in the US for 2015 varied between \$5.25 and \$12.85²⁴. For 33 of the states the cost varied between \$5.25 and \$6.89, and for the rest between \$7.37 and \$12.85. All calculations were carried out using \$6 and \$10 as prices for a pack of 20 cigarettes. The total cost for 32.2 years of smoking was calculated for 10, 15, 20, 30 and 40 cigarettes/day. In addition, the total cost of lifetime smoking from the age of 17.8 years of age to the age of 78.8 years of age was calculated. It is impossible to accurately assess the start of smoking for the average patient; for this study it is set at 17.8 years of age.

The following formulas were used:

Life cost for non-smokers: $IT + (SPT \times 31.2) + ((RT \times 4.7) / 2) + (TR \times 0.54)$

(IT= Initial therapy, SPT=Supportive/maintenance therapy, RT= Re-treatment, TR= Tooth replacements).

Scenario 1.

Life cost for stable patients who are smokers: $IT + (SPT \times 31.2) + ((RT \times 4.7) / 2) + (TR \times 1.12)$

Scenario 2. Life cost for stable patients who are smokers and require extra maintenance and re-treatment (ie. One extra maintenance visits per year and 50% extra re-treatment:

$IT + (SPT \times 31.2) \times 1.5 + ((RT \times 4.7) / 2) \times 1.5 + (TR \times 1.12)$

Scenario 3. Life cost for stable patients who are smokers and require extra maintenance and re-treatment at 100% increase (ie two extra maintenance visits per year and twice the

amount of re-treatment): $IT+(SPT \times 31.2) \times 2 + ((RT \times 4.7) / 2) \times 2 + (TR \times 1.12)$

Sensitivity analysis

A sensitivity analysis was completed using a range from 10% higher to 10% lower in the projected cost of the items of periodontal treatment (initial therapy, maintenance, re-treatment) and the fixed restorative work.

Results

Life-time cost of periodontal treatment for a non-smoker

The cost of initial periodontal therapy for the average patient was \$6676. The cost of SPT visits was \$9110 and the cost of RT was \$5170. It was assumed that patients who completed periodontal treatment and complied with a strict maintenance programme were likely to request the replacement of lost teeth. The cost of replacing teeth lost during periodontal maintenance was added to the cost of periodontal treatment to calculate the total life-time cost.

The total life-time cost in non-smokers who replaced lost teeth with bridgework or implants was \$22846 (discounted value \$ 8820).

Scenario 1. The cost for smokers, excluding the cost of cigarettes was \$24876 (discounted value \$9603), which represented a 8.8 % increase.

Scenario 2. The cost for unstable maintenance patients who smoke and require an extra 50% added maintenance care and re-treatment to prevent further tooth loss was \$32016 (discounted value \$12360) an increase of 40.1%.

Scenario 3. The cost for unstable maintenance patients who smoke and require an extra 100% added maintenance care and re-treatment to prevent further tooth loss was \$39156 (discounted value \$15116) an increase of 71.4%.

Life-time treatment cost for smokers including the cost of cigarettes

The costs of smoking ranged from \$ 35259 for those who smoked 10 cigarettes/day at \$6 /packet to \$ 235060 for those who smoked 40 cigarettes per day at \$10 /packet over the 32.2 year maintenance period (Table 1). The life-time cost of treatment including smoking was \$93364 in patients who smoked 20 cigarettes per day at \$6 /packet. In this case the cost of cigarettes accounted for almost 75.5% of the total cost, i.e. life-time periodontal therapy including tooth replacements made up less than 25% of the total cost.

The number of times life-long cost (61 years) of smoking exceeded life-time cost of periodontal therapy varied from 2.7 for 10 cigarettes/day at \$6 /packet to 17.9 for 40 cigarettes/day at \$10/packet (Table 2). Smoking 40 cigarettes at \$10 a packet for 3.4 years would pay for the entire life-time periodontal treatment.

The number of single tooth replacements (three unit bridge or implant) possible for the total cost of smoking was 20.0 for 10/day at \$6/packet.

A sensitivity analysis of varying the costs of periodontal treatment and tooth replacements by up to 10% in relation to the number of times smoking exceeded the cost of periodontal therapy is shown in Table 2.

Discussion

This study shows that the effect of smoking adds 8.8% to the financial cost of life-time periodontal therapy in stable maintenance patients; 40.1% in smokers who require one extra maintenance visit per year and extra re-treatment; and 71.4% in smokers who

require twice the amount of maintenance care and re-treatment to keep them stable. The calculations assume that all patients comply fully with treatment and maintenance treatment. The main reasons for the added cost is the extra treatment required to maintain the dentition both in terms of additional periodontal therapy as well as a higher rate of tooth loss resulting in added prosthetic replacements.

The study also highlights the fact that the life-time cost of periodontal therapy is only equivalent to about 25% of the cost of smoking for patients who smoke 20 cigarettes per day. Smoking a pack a day exceeded the cost of periodontal therapy by a factor of 5.4 and 9.0 for packs costing \$6 and \$10 respectively. Smoking 40 cigarettes/day at \$10/pack for 3.4 years would pay for the entire life-time cost of periodontal therapy.

In addition to being a cost benefit to stop smoking, it also improves the clinical periodontal outcomes within one year¹⁵ and it reduces subsequent tooth loss²⁵. Furthermore, at the population level, it has been shown that a reduction in the smoking level in Sweden coincided with a reduction in the level of periodontal disease over several years²⁶.

It is also desirable to promote smoking cessation due to a number of complicating factors associated with the treatment of periodontal disease in smokers. A recent study¹² showed that smokers respond less favourably to both non-surgical and surgical periodontal therapy compared with non-smokers, in particular in plaque infected sites. Further, it may be more difficult to assess and diagnose the stability of periodontal disease during the SPT because there is less bleeding on probing in deeper pockets in smokers than in non-smokers⁵. A poorer response to periodontal therapy adds to both the financial and human cost of the treatment^{10,11}. Added cumulative human cost due to the smoking is difficult to assess. Some data exists from the present patient population in terms of anxiety and

discomfort associated with periodontal and implant therapy, while data is lacking in terms of prosthetic therapy, tooth extractions, acute periodontal infections, discomfort due to loose teeth and other complications prior to extractions^{16,27,28}. However, an increase in human costs in smokers may help to explain the poor compliance with SPT reported in a recent study²⁹.

Limitations of the study

The model used in this study was originally developed from a Norwegian specialist practice which may reduce the generalizability of the results. However, the basic principles of initial periodontal therapy followed by maintenance treatment with replacements of lost teeth is universally well established and should apply to most specialist and university settings. Furthermore, the average values used as fixed values in the present study, for example patients' age at the initial therapy, the amount of initial therapy and the amount of smoking between the levels used can also be regarded as variables. Thus the results may not necessarily apply directly to each individual patient. In addition, several educational, behavioural and economic aspects may influence the outcomes. However, to calculate sensitivity analysis for each potential variable is not within the scope of this study as the aim was to make a simple illustrative model of how smoking affects the average patient's cost.

Cost of smoking

It is not possible to calculate the exact cost of smoking due to the marked variation between the costs of cigarettes in the different states. In addition, it may be possible to reduce the total cost of smoking by a systematic purchase of duty free cigarettes. Further, the average life span of smokers is shorter than for non-smokers and thus the total life-

long cost will be lower. However, these factors are likely to have only marginal effects on the average figures reported. In addition, the aspects of quitters and oscillators have not been addressed in this model neither in the context of cost, nor on the outcome. It is difficult and often impossible to monitor the smoking habits longitudinally for a large group of patients in terms of increasing, decreasing, quitting and re-starting smoking.

Treatment cost

It is difficult to calculate accurate treatment costs due to the extreme variations in dental fees published by the American Dental Association²³. A sensitivity analysis using 10% lower and higher for the dental fees is used, however, this will obviously not cover any variations beyond the $\pm 10\%$. In addition, the level of insurance cover will influence the cost for individual patients. No attempts to incorporate cost reducing effects for individual patients have been carried out.

It is likely that there will be a further increase in total cost during maintenance treatment for patients who smoke and have had tooth replacements carried out with implants as several studies have shown more complications with implant treatment in smokers than non-smokers³⁰.

It must be underlined that the findings of this study apply to compliant stable periodontal maintenance patients and not necessarily to smoking patients who are non-compliant or non-responsive to periodontal therapy. Compliance is lower in smokers than in non-smokers^{29,31,32}, so it is likely that any failure of compliance would result in increasing the rate of tooth loss with significant implications for increased costs.

For the scenario 3 patients, increasing the maintenance and re-treatment by 100% may not be sufficient to stabilise all these patients in terms of further tooth loss. Some of these

patients may turn out to be non-responding to treatment

From the same practice setting⁸, it is reported that 2.2 % of the patient population did not respond to treatment and had a 35-times higher rate of tooth loss than did stable periodontal patients who responded to treatment. Obviously there would be a vastly increased cost of tooth replacement for these patients. As a great number of teeth need to be replaced, it is likely that these are not all replaced by single implants or three- unit bridges, but instead by larger bridges on remaining teeth or strategic placements of fewer implants. Therefore an attempt at cost calculation for these patients would be very difficult and the results would be highly speculative.

Conclusion: The present study shows that smoking adds considerable financial cost to the life-time treatment of periodontal disease. The cost of smoking dwarfs the cost of periodontal therapy.

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Cigarettes per day	Total cost cigarettes 61 yrs		Saving cost cigarettes 32.2 yrs	
	\$6	\$10	\$6	\$10
10	66795	111325	35259	58765
15	100193	166988	52889	88148
20	133590	222650	70518	117530
30	200385	333975	105777	176295
40	267180	445300	141036	235060

Table 1. Showing total life-long cost of smoking for 61 years and the savings achieved if patents can be encouraged to stop smoking at the initial therapy stage (32.2 years). Values are given for both \$6 and \$10 dollars for 20 cigarettes.

Cigarettes per day	Number of times life-long smoking costs exceeds the cost of life-time periodontal therapy (\pm 10% treatment costs).	
	\$6	\$10
10	2.7(2.4-30.0)	4.5 (4.1-5.0)
15	4.0 (3.7-4.5)	6.7 86.1-7.5)
20	5.4 (4.9-6.0)	9.0 (8.2-10.0)
30	8.1 (7.3-9.0)	13.5 (12.2-14.9)
40	10.8 (9.8-12.0)	17.9 (16.3-19.9)

Table 2. Showing the number of times smoking costs exceeds the cost of life-time periodontal therapy using \pm 10% sensitivity for treatment costs and smoking costs at \$6 and \$ 10 for 20 cigarettes.

