HEALTH ECONOMICS
Health Econ. **17**: S83–S93 (2008)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hec.1326

COSTS AND PRICES OF SINGLE DENTAL FILLINGS IN EUROPE: A MICRO-COSTING STUDY

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SUMMARY

Dental fillings represent an established procedure to treat tooth decay. The present paper provides a cost comparison of dental filling procedures across nine European countries. More specifically, the paper aims to estimate the costs and prices (i.e. reimbursement fees) of a single dental filling procedure in an approximately 12-year-old child with a toothache in a lower molar who presents at a dental practice, as described in a case vignette. Both amalgam and composite fillings were examined. Total costs were determined by identifying resource use and unit costs for the following cost components: diagnostic procedures, labour, materials, drugs, and overheads. Altogether, 49 practices provided data for the cost calculations. Mean total costs per country varied considerably, ranging from €8 to €156. Labour costs were the most important cost driver in all practices, comprising 58% of total costs. Overhead costs were the second-most important cost component in the majority of countries. Actual cost differences across practices within countries were relatively small. Cost variations between countries were primarily due to differences in unit costs, especially for labour and overheads, and only to a lesser extent to differences in resource use. Finally, cost estimates for a single dental filling procedure based on reimbursement fees led to an underestimation of the total costs by approximately 50%. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: dentistry; dental filling; Europe; cost comparison; healthcare costs

INTRODUCTION

Dental fillings represent an established procedure to treat tooth decay. Dental filling procedures involve assessing the cavity, preparing the filling, excavating decayed material, and filling the tooth. The procedure is usually carried out by dentists, with or without the assistance of dental nurses, and is generally provided at independent dental practices.

Dental fillings are one of the services explored as part of work package 9 of the EU *Health*BASKET project. More specifically, the case vignette in question concerns 'an approximately 12-year-old child with a toothache in a lower molar who presents at a dental practice. After diagnosis, the dentist decides to place an amalgam filling.' The vignette was defined in detail to ensure that the same case was considered in each country and dental practice. Dental fillings performed as an inpatient procedure were excluded from the study.

The aim of the present paper was to estimate resource use, total costs, and prices (i.e. reimbursement fees) for a single dental filling procedure in nine participating EU member states: Denmark, England, France, Germany, Hungary, Italy, The Netherlands, Poland, and Spain. Dental fillings allow for relatively straightforward cost calculation and comparison, because they involve a relatively homogeneous procedure that is performed in a small organisational unit in primary care.

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BACKGROUND

A dental filling is indicated when a caries lesion is found in a molar tooth. Assessment by a dentist determines whether treatment is required and may include diagnostic procedures such as medical imaging, vitality testing, cold testing, and percussion testing. Therapy involves preparing the filling, excavating decayed material from the affected tooth, and placing the filling into the cavity. Dental amalgam has been used as a restorative material in dentistry for more than a century and is made by combining elemental mercury, silver, tin, copper, and possibly other metallic elements. Although a second visit is desirable to polish the amalgam after placement, amalgam fillings are quick and easy to apply (Rateitschak *et al*., 1994).

In recent years, a shift from dental amalgam to adhesive dentistry with resin composites has taken place in many countries. Composite fillings are a mixture of glass or quartz filler in a resin medium that produces a tooth-coloured filling (Hoffmann-Axthelm, 1995). Applying a composite filling is more time consuming (Rateitschak *et al*., 1994), but has a variety of obvious advantages. Many dentists prefer composites for aesthetic, toxicological, or ecological reasons (Lehmann, 1993). Composites require removing less tooth structure, cause less sensitivity to hot and cold, have a strengthening effect on the remaining tooth, and allow for individual colour nuances (Opdam, 2005). In Germany and The Netherlands, the use of dental amalgam has ceased almost entirely, particularly among younger patients (Hoffmann-Axthelm, 1995; Opdam, 2005).

To our knowledge, no publications over the past decade have explored the costs of single dental filling procedures in Europe. However, Oscarson *et al*. (1998) assessed the relative impact of cost components on the total costs of dental care in Sweden. In that study, labour turned out to be the major cost driver, comprising 67% of total costs. Overheads accounted for 25% of the total costs.

Some studies have evaluated the long-term costs of different filling materials (Mjör *et al*., 1997; Sjögren and Halling, 2002) and the cost-effectiveness of different types of dental treatments for caries prevention (Griffin *et al*., 2002; Jokela and Pienihakkinen, 2003; Kervanto-Seppala *et al*., 2000), large substance loss (Brägger *et al*., 2005; Kelly and Smales, 2004; Kolker *et al*., 2006), class II restorations (Tobi *et al*., 1999; Yip *et al*., 2002), and asymptomatic disease-free third molars (Edwards *et al*., 1999). Even though treatment time was recognised by most papers as crucial for explaining cost variation, it was included as a cost estimate in only three studies (Jokela and Pienihakkinen, 2003; Kervanto-Seppala *et al*., 2000; Tobi *et al*., 1999). The other economic evaluations used general service fees to approximate costs.

METHODS

A standardized micro-costing methodology was used to ensure that the identified cost differences would reflect only actual cost differences. Cost components included diagnostic procedures, labour, materials, drugs, and overheads. In each country, a sample of dental practices was identified that was representative of the overall practice setting and treatment patterns in that country. Dentists in Denmark, France, Hungary, Italy, The Netherlands, Poland, and Spain were asked personally by the investigators whether they would like to participate in the study. In England and Germany, 20 and 175 randomly selected dentists, respectively, were asked by (e-)mail if they would like to participate. In addition, a request was placed in the dental information bulletin published by the German Dental Association.

Information on resource use and the unit costs of cost components was collected from between 3 and 15 representative dental practices per country. Dentists were asked to provide information on the last 10 patients who matched the vignette description or to estimate resource use and unit cost data based on an average patient. Although the case vignette restricted the use of restorative materials to amalgam, the decision was ultimately made to examine both amalgam and composite fillings, as some practices no longer used amalgam. Using standardised reporting templates, data were collected by means of

DOI: 10.1002/hec

face-to-face interviews (France, Germany, Italy, Poland, and Spain), telephone interviews (Denmark, France, Germany, Hungary, and The Netherlands), and questionnaires (England, France, Germany, Hungary, The Netherlands, and Poland). Alternative sources were used to gather additional information, including national/local health registries (Denmark, England, France, and The Netherlands) and manufacturers (Germany).

Labour costs for dentists and dental assistants were based on treatment time (length of session) and multiplied by standardised costs per time unit. Costs per time unit were determined on the basis of gross income (including social security costs) and either the number of workable hours (Denmark, England, France, Germany, Hungary, and The Netherlands) or the number of hours dedicated to direct patient care only (Italy, Poland, and Spain). Labour not directly involved in the treatment process was included in overheads.

Although the cost items included in the overheads varied somewhat from practice to practice, these generally included the costs of rent, utilities (electricity, heat, and water), cleaning and waste management, insurance, telecommunication, equipment, and administration. Overhead costs were based on average treatment time, total overhead costs per year, and either the number of workable hours (England, Germany, Hungary, and The Netherlands) or the number of hours dedicated to direct patient care only (France, Italy, Poland, and Spain). In Denmark, Italy, and Poland, some estimations of overhead costs were provided directly by the dentists.

In addition to descriptive statistics, analyses of variance were used to evaluate variations in variables between and within countries. Normal distribution of total costs in the different practices was assessed using the Kolmogorov–Smirnov test ($P = 0.085$).

The dental practices in all participating countries were included in an ordinary least squares (OLS) regression analysis, taking mean total costs as the dependent variable, and practice, treatment, and country characteristics as explanatory variables. Practice characteristics consisted of the 'type of practice' (independent practice yes/no), the 'number of dentists per practice', and the 'number of dental assistants per dentist'. These variables served as a proxy to control for the type and the size of the practices. Treatment characteristics consisted of the 'percentage of patients receiving amalgam', the 'percentage of patients receiving medical imaging services', and 'treatment time'. These variables served as a proxy for treatment decisions taken at a particular practice. Country variables were included to control for differences between countries. As a supplement, random effects regression modelling was applied to take into account the fact that data originated from patients seen in various countries and practices (Singer, 1998). In this analysis, both countries and practices were included as random effects, whereas practice, treatment, and country characteristics were included as fixed effects. Finally, purchasing power parities (PPPs) were included in the random effects model to control for differences in price levels between the countries. PPPs were based on the latest Organisation for Economic Co-operation and Development statistics on PPPs and comparative price levels.

Reimbursement fees are supposed to cover all aspects of the dental filling procedure, including assessment of the cavity, preparation of the filling, excavation of decayed material, and placement of the filling. Therefore, the last analysis involved calculating Pearson's correlation coefficients to investigate whether reimbursement fees represent a good cost estimate for mean total costs.

Statistical analyses were conducted with the software packages SPSS version 13.0 for Windows and SAS version 8.02. *P*-values less than 0.05 were considered statistically significant. The perspective of the study was that of the practitioner, and all costs were measured in values of 2005. Mean exchange rates for 2005 were used.

RESULTS

Data for the cost calculations were provided by a total of 49 practices, 15 of which (31%) were located in Germany. In most countries, it was difficult to recruit dentists who were willing to participate.

DOI: 10.1002/hec

Table I. Practice characteristics per country

Countries	No. of practices included	Independent practice (%)	Community-based practice (%)	Outpatient department of hospital (%)	Private (%)	Public (%)	Number of dentists per practice	Number of dental assistants per practice	No. of other supporting staff per practice
England	4	0	100	0	0	100	[a]	[a]	[a]
Italy	5	100	0	0	80	20	1.0	1.0	0.0
Spain	4	100	0	0	100	0	1.5	2.5	1.0
Germany	15	100	0	0	100	0	1.7	3.7	0.7
The Netherlands	5	100	0	0	100	0	2.0	1.4	0.0
Denmark	4	0	100	0	0	100	26.3	46.5	12.1
France	4	100	0	0	100	0	1.3	0.5	0.3
Poland	5	100	0	0	0	100	2.6	[a]	[a]
Hungary	3	67	0	33	67	33	1.0	1.0	0.7

[a] Data not available.

However, no association was found between the way in which dentists had been approached (i.e. personally or through random selection) and mean total costs ($P = 0.162$).

Practice characteristics

Practice characteristics per country are summarised in Table I. Most participating practices were independent dental practices. Although independent practices are generally private, all practices in Poland (5/5) and one practice in Italy (1/5) were affiliated with public institutions. In Denmark, dental care is provided through public municipal dental care organisations, which generally have more dentists (26.3 dentists) and dental assistants (46.5 assistants) per practice (compared with an average of 1.6 dentists and 1.7 assistants in the other countries). Overall, mean total costs did not differ significantly between single and group practices ($P = 0.675$).

Cost comparison between countries

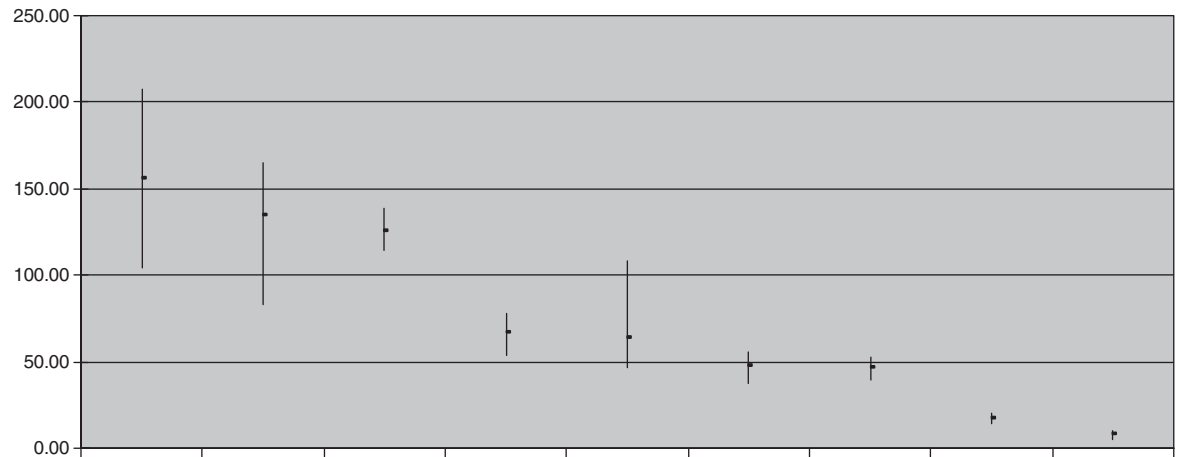
An overview of mean total costs per country is given in Figure 1 and Table II. The mean total costs for all countries were €74 (SD 53), ranging from €8 in Hungary to €156 in England. Variations were caused by large differences in the costs of labour ($P < 0.001$), materials ($P < 0.001$), imaging ($P < 0.001$), and overheads ($P < 0.001$).

Without exception, labour costs were the most important cost driver in all countries and practices. Labour costs accounted for 58% of total costs (€43; SD 33) on the average, and for as much as 77 and 70% of total costs in Denmark and England, respectively. The large differences in labour costs between countries were essentially caused by wide variations in unit costs, especially for the dentist ($P < 0.001$). Dentist costs per minute ranged from €0.09 in Hungary to €2.88 in England (Table II). However, the relatively high dentist costs in England also included material costs, which makes straightforward comparisons difficult.

Although there appeared to be consensus among dentists on treatment time ($P = 0.309$), length of session was relatively long in Spain (64 min vs an average of 35 min in the other countries; Table II). Dentists spent as much time with the patients as did dental assistants on the average (i.e. 37 min), but dentists' unit costs were four times higher (€0.92 vs €0.22 per minute). As a result, 81% of labour costs in our sample were attributable to dentist costs.

Overhead costs were the second-most important cost component in most countries (mean €18; SD 17). Overhead covered 24% of the total costs, ranging from 7% in England to as much as 40% in Spain and 41% in Germany. This wide variation was due to, for the most part, large differences in unit costs,

DOI: 10.1002/hec



	England	Italy	Spain	Germany	Netherlands	Denmark	France	Poland	Hungary
Max	207.63	165.37	138.97	77.84	108.23	55.67	53.12	20.53	10.08
Min	103.81	83.00	114.80	54.14	46.09	37.31	39.60	14.02	5.29
▪ Mean	156.02	134.93	125.23	66.92	63.81	47.45	46.47	17.65	7.97

Figure 1. Comparison of dental filling costs between countries (costs in Euros, 2005)

ranging from €0.07 in Hungary to €1.01 in Italy ($P = 0.003$; Table II). The number of hours on which labour and overheads were based (i.e. workable hours or hours dedicated to direct patient time only) did not have an impact on mean total costs ($P_{\text{labour}} = 0.123$ and $P_{\text{overheads}} = 0.618$).

The remaining costs consisted primarily of the costs of diagnostic procedures (€8; SD 13) and materials (€5; SD 6). Diagnostic procedures represented a high share of total costs in England (23%) and The Netherlands (33%). Imaging costs ranged from €0.11 in Germany to €35 in England. A significant difference was found for the percentage of patients who underwent diagnostic procedures ($P = 0.012$; Table II). On average, 7 out of 10 patients underwent imaging (i.e. X-ray and bitewing radiographs). However, this proportion was only 2 out of 10 in Germany. Also, unit costs for imaging varied widely, ranging from €0.30 in France to €39 in The Netherlands ($P = 0.001$; Table II), which may reflect different mixes of imaging services.

Material costs played an important role in Hungary and Italy. Hungary showed a high relative share of material costs (20% vs an average of 7% in the other countries), whereas a high absolute level was observed in Italy (€20 vs an average of €2 in the other countries). The latter finding was primarily due to the high costs of the filling material (€15 vs an average of €1 in the other countries).

In total, 59% of patients received an amalgam filling (Table II). The lowest percentages of amalgam fillings were found in Germany (27%) and The Netherlands (10%). On average, unit costs for amalgam fillings were more than 2 times lower than those for composite fillings; in Germany and The Netherlands, however, they were 8 times lower (Table II). Nevertheless, the percentage of patients receiving amalgam had no significant influence on mean total costs ($P = 0.661$).

No significant differences between countries were observed with regard to resource use or the unit costs of anaesthetics ($P = 0.264$ and 0.111, respectively; Table II).

Within-country cost comparisons

Overall, variations in mean costs between practices within individual countries were relatively small. Analyses of variance revealed within-country variations for the treatment time of dental assistants

DOI: 10.1002/hec

Table II. Resource use and unit costs of the cost components (rounded) (costs in Euros, 2005)

	England[a]	Italy	Spain	Germany	The Netherlands	Denmark[a]	France	Poland[a]	Hungary[a]	Mean	SD
Diagnostic procedures											
Imaging	35	11	3	0	21	1	0	1	0	8	12
Resource use (no. of units)	0.88	0.70	1.00	0.20	0.54	0.78	1.00	0.40	0.60	0.68	0.27
Unit costs (€ per unit)	40.35	16.00	2.51	0.53	39.00	0.81	0.30	3.73	0.53	11.53	16.70
Labour											
Dentist	97	48	61	26	24	21	24	8	2	35	30
Resource use (min)	33.75	36.00	63.75	33.93	31.93	33.75	32.50	47.82	23.50	37.44	11.68
Unit costs (€ per min)	2.88	1.32	0.96	0.78	0.74	0.63	0.75	0.16	0.09	0.92	0.82
Dental assistant	11	18	7	8	9	15	1	2	2	8	6
Resource use (min)	42.36	44.00	63.75	33.93	25.08	41.50	10.75	40.50	33.50	37.26	14.48
Unit costs (€ per min)	0.27	0.41	0.12	0.25	0.34	0.37	0.10	0.05	0.06	0.22	0.14
Materials											
Amalgam	[c]	3	3	0	0	0	0	[b]	1	0	0
Resource use (no. of units)	1.00	0.40	1.00	0.27	0.10	0.38	0.75	1.00	0.45	0.59	0.35
Unit costs (€ per unit)	[d]	8.40	3.00	0.30	0.33	0.45	0.45	[d]	1.30	2.03	2.97
Composite	[d]	12	[d]	2	2	1	0	[d]	1	3	5
Resource use (no. of units)	0.00	0.60	0.00	0.73	0.90	0.63	0.25	0.00	0.55	0.41	0.35
Unit costs (€ per unit)	[d]	20.00	[d]	2.25	2.73	0.85	1.36	[d]	1.30	4.75	7.50
Disposables	[c]	5	1	2	0	0	4	2	0	2	2
Drugs											
Anaesthetic	1	3	[c]	0	0	1	0	[b]	0	1	1
Resource use (no. of administrations)	1.00	0.97	[d]	0.71	0.78	0.95	1.00	[d]	0.85	0.89	0.12
Unit costs (€ per administration)	0.57	2.90	[d]	0.46	0.51	0.85	0.24	[d]	0.30	0.83	0.93
Overheads	11	36	51	27	7	9	14	4	2	18	17
Resource use (min)	34	36	64	34	32	34	33	48	24	37.44	11.68
Unit costs (€ per min)	0.31	1.01	0.80	0.80	0.22	0.27	0.43	0.08	0.07	0.44	0.34
Total	156	135	125	67	64	47	46	18	8	74	53
Patient co-payment	0	19	0	11	0	[d]	14	0	0	5	8
Reimbursement	27	19	50	66	61	[d]	32	9	7	34	23

[a] Danish krone (kr) 1 = €0.1342; British pound (£) 1 = €1.463; 1 Hungarian forint (Ft) = €0.004047, and Polish zloty (zł) 1 = €0.2500.
[b] Subsumed in disposables.
[c] Subsumed in labour.
[d] Not applicable.

DOI: 10.1002/hec

($P = 0.001$), as well as for the unit costs and total costs of amalgam ($P_{\text{unit costs amalgam}} = 0.005$ and $P_{\text{total costs amalgam}} = 0.001$). Furthermore, broad within-country variations were found for the total costs of imaging (Germany and Hungary); for treatment time and the unit costs of dental assistants (France); for resource use and unit costs of amalgam (Denmark, Germany, Italy, and The Netherlands); for the unit costs and total costs of composites (France); for the total costs of disposables (Italy): for the use of anaesthetics (Poland); and for the unit costs and total costs of anaesthetics (France).

Although practice characteristics likely influenced differences in the unit costs of overheads, our sample was too small to draw reliable conclusions on possible associations. Even so, in Hungary, unit costs were 3 times higher in private practices than they were in public practices. In Spain, urban practices reported higher rental rates than rural practices.

In Italy, the mean costs of public practices were much lower than those of private practices (€83 vs an average of €148). This disparity was attributable primarily to the lower unit costs of imaging, labour, and disposables in public practices. Mean costs in the one outpatient department in Hungary included in our sample were much lower than the costs seen in the independent practices in that country (€5 vs an average €9). This was due to lower cost estimates of all cost components except for overheads. In The Netherlands, the mean costs in one practice were considerably higher than those seen in the other practices (€108 vs an average €53). These higher mean costs were primarily due to longer sessions.

Regression analyses

Table III gives the results of the different regression models that were constructed to examine the degree of association between total costs and practice characteristics. In all cases, the dependent variable was total costs. The first set of models, labelled as model 1, included practice characteristics, treatment characteristics, and countries. Of the practice and treatment characteristics included in these analyses, only two were significantly associated with mean total costs: use of medical imaging and treatment duration. Specifically, the use of medical imaging was associated with an increase in mean total costs of €25.80 ($P < 0.001$), and 1 extra minute of treatment was associated with an additional €1.14 increase in mean total costs ($P < 0.001$). The use of a random effects regression model (model 1b) led to regression coefficients and standard errors that were very similar to those seen in the OLS model (model 1a). The combination of PPP-adjusted total costs and a random effects regression model (model 1c) also resulted in similar values.

Model 2 contained only practice characteristics and treatment characteristics. Unlike model 1, the number of dentists per practice was significantly associated with total costs when OLS regression was used (model 2a). Practices with more dentists showed lower total costs than practices with fewer dentists ($P < 0.10$). Independent practices and number of assistants per dentist were not associated with total costs. As with model 1, the use of medical imaging and longer treatment duration were associated with higher costs, while the use of amalgam was not significantly associated with total costs. When a random effects model (model 2b) was estimated instead of OLS regression, three changes were noticed. Firstly, the number of dentists per practice was not significantly associated with total costs. Secondly, the coefficients for medical imaging and treatment duration were slightly smaller. Lastly, the standard errors were approximately half the size of those seen using OLS regression. The use of PPP-adjusted total costs in a random effects model (model 2c) resulted in coefficients and standard errors that were similar to those seen with unadjusted total costs and random effects (model 2b).

Model 3 was the simplest of the three models and contained only treatment characteristics. The associations seen between treatment characteristics were very similar to those seen in model 2. As with model 2, medical imaging and longer treatment duration were associated with higher costs, whereas the use of amalgam was not significantly associated with total costs. The coefficients for medical imaging and treatment duration were slightly smaller. Also, the use of a random effects model (model 3b) resulted in standard errors that were approximately half the size of those seen using OLS regression

DOI: 10.1002/hec

Table III. Regression models to explain total costs per practice ($n = 49$) (costs in Euros, 2005)

	Model 1a Without random effects Without PPP		Model 1b With random effects Without PPP		Model 1c With random effects With PPP		Model 2a Without random effects Without PPP		Model 2b With random effects Without PPP		Model 2c With random effects With PPP		Model 3a Without random effects Without PPP		Model 3b With random effects Without PPP		Model 3c With random effects With PPP	
Independent variable	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Practice characteristics																		
Independent practices	−19.69	18.29	−19.77	19.32	−23.73	20.71	−22.37	22.05	−25.36	17.54	−31.35	18.94	—	—	—	—	—	—
Dentists per practice	−0.32	0.33	−0.31	0.34	−0.27	0.37	−1.56	*0.80	−0.37	0.34	−0.31	0.37	—	—	—	—	—	—
Assistents per dentist	−3.52	4.20	−2.86	3.61	−2.97	3.90	10.10	6.63	−2.89	3.55	−2.98	3.85	—	—	—	—	—	—
Treatment characteristics																		
Amalgam	−6.41	6.36	−7.20	7.12	−7.78	7.63	−23.32	14.60	−6.59	7.03	−7.31	7.55	−9.03	14.62	−5.20	8.09	−6.06	8.87
Medical imaging	25.80	***9.20	25.83	**9.65	28.52	***10.35	42.01	**16.39	28.16	***9.34	31.25	***10.04	38.85	**16.77	22.83	**9.45	25.06	**10.36
Treatment time	1.14	***0.30	1.18	***0.30	1.27	***0.33	1.62	***0.54	1.24	***0.30	1.31	***0.32	1.13	**0.56	1.44	***0.30	1.57	***0.33
Countries																		
Denmark	−46.66	*23.17	−48.02	*24.47	−41.90	26.23	—	—	—	—	—	—	—	—	—	—	—	—
France	−42.85	***14.15	−42.47	***13.92	−45.32	***14.95	—	—	—	—	—	—	—	—	—	—	—	—
Hungary	−67.53	***13.75	−67.30	***14.16	−78.32	***15.2	—	—	—	—	—	—	—	—	—	—	—	—
The Netherlands	−16.01	10.13	−16.28	10.14	−17.73	10.89	—	—	—	—	—	—	—	—	—	—	—	—
Poland	−73.23	***14.58	−73.08	***13.77	−88.77	***14.82	—	—	—	—	—	—	—	—	—	—	—	—
England	87.01	***29.06	86.84	***29.92	100.20	***32.1	—	—	—	—	—	—	—	—	—	—	—	—
Italy	48.90	***10.41	48.50	***10.41	49.98	***11.18	—	—	—	—	—	—	—	—	—	—	—	—
Spain	6.58	15.91	4.78	16.10	−12.83	17.28	—	—	—	—	—	—	—	—	—	—	—	—

Germany served as a reference country and was therefore not included in this table.
*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$.

DOI: 10.1002/hec

(model 3a). Finally, the use of PPP-adjusted total costs in a random effects model (model 3c) resulted in coefficients and standard errors that were similar to those seen with unadjusted total costs and random effects (model 3b).

Reimbursement: Pearson's correlation coefficient

Table II also presents the fees charged by dental practices to patients and their healthcare insurers. There was a surprisingly weak positive linear relationship between reimbursement (including patient co-payment) and the total costs of dental filling per country (Pearson's correlation coefficient: $R = 0.280$).

Dental practices were generally more likely to make a loss than a profit when performing dental filling procedures. Among countries incurring costs in excess of reimbursement, the magnitude of the mean loss incurred was €52, with figures ranging from less than €1 in France and Hungary to €129 in England. However, the €27 reimbursement fee in England (Table II) reflected National Health Service reimbursement to community dentists for placing an amalgam filling and was considerably lower than the national reimbursement rate for a child's first outpatient visit for orthodontic treatment (€208), which most closely reflected the vignette description.

DISCUSSION AND CONCLUSION

This study is the first to compare the costs of single dental filling procedures in Europe. The mean costs of a single dental filling amounted to €74, which was much higher than the average sum of patient co-payment and reimbursement (€39). According to this comparison, using fees as a cost estimate for a dental filling would have led to a 50% underestimation of total costs. This disparity was almost completely due to relatively low reimbursement rates in England, Italy, and Spain. Charges by dental practices to patients and their healthcare insurers vary widely between countries, because charges are highly dependent on national health payment systems, as well as on political and economical factors. A fairly strong direct correlation appears to exist between reimbursement (including patient co-payment) and gross domestic product per capita, with less wealthy countries providing lower levels of reimbursement ($R = 0.767$).

As expected, treatment time was clearly very important in determining the total costs of episode of care described in the vignette. This was particularly true if we consider that the two most important cost drivers (i.e. labour and overheads) were based on this estimate. However, absolute cost differences between countries were attributable primarily to differences in unit costs. These differences in unit costs were partly reflected in differences in gross domestic product per capita ($R = 0.617$).

Our regression analyses revealed a number of interesting findings. The between-country differences in total costs were evident throughout the analyses. These differences did not change and were not sensitive to the presence or absence of any practice or treatment characteristics in the model. With one exception, the practice characteristics that were examined in this study were never significantly associated with total costs. This one exception involved a negative and marginally significant association ($P = 0.058$) between total costs and the number of dentists. However, once information about the country was included in the analysis, this association disappeared. Two treatment characteristics were consistently associated with higher total costs: use of medical imaging and longer treatment time. The use of medical imaging and an additional minute of treatment time were associated with extra costs that ranged from approximately €23 to €42 and from €1.18 to €1.62, respectively, depending on the structure and contents of the regression model. Lastly, PPP adjustment had a minimal overall impact on the results, particularly since the PPPs for most of these countries were fairly similar.

Oscarson *et al.* (1998) conducted a micro-costing study to determine the relative impact of cost components on the total costs of dental care in Sweden (Oscarson *et al.*, 1998). Different methods for the valuation of treatment time and for allocating the unit costs of overheads were used. The results of their study were very similar to those of the present study. Labour and overheads contributed to 67 and

DOI: 10.1002/hec

25% of the total costs, respectively (vs 58 and 23% in our study). Furthermore, total costs were highly sensitive to changes in length of session. Decreasing treatment time by 10 and 30% reduced the average costs of treatment time by approximately 10 and 40%, respectively. The study also confirmed sensitivity to the unit costs of labour, although this sensitivity was not as high as that of length of session.

Our study confirmed that the unit costs of amalgam are considerably lower than those of composites (€2.03 vs €4.75; Table II). Tobi *et al*. (1999) assessed the incremental cost-effectiveness of the use of composite resins and amalgam for the restoration of amalgam class II restorations. Treatment time was prospectively measured and used to approximate treatment costs. It was concluded that amalgam restorations were associated with about half the treatment time required for composite restorations. Other studies have also demonstrated favourable costs for amalgam, albeit over the long term. Mjör *et al*. (1997) compared the relative costs of direct class II restorations for different filling materials in England over a patient's lifetime. Their study illustrated the relatively low life-long costs of amalgam restorations and the relatively high costs of treatment using a resin-based composite. A comparable conclusion was drawn by Sjögren and Halling (2002) who evaluated the theoretical long-term treatment costs of class II molar restorations in Sweden. The use of composite fillings was twice as costly over 10 years as the use of amalgam fillings.

Even though several studies have assessed the cost-effectiveness of dental treatments, only few address the use of amalgam or composites using fees as a proxy for actual costs. In a study by Sjögren *et al*., the mean initial costs of amalgam and composite direct class II molar restorations were €60 and €77, respectively (base year: 2006; Sjögren and Halling, 2002). Kolker *et al*. (2006) assessed the costs of large amalgam fillings and crowns in the United States for restoring teeth that had been severely compromised due to a loss of tooth structure. Initial average costs for teeth with crowns were €641, while the initial costs assigned to teeth with large amalgam fillings were €104. A study by Kelly *et al*. that assessed the relative cost-effectiveness in Australia of alternative methods for restoring large tooth substance loss determined that the discounted costs of amalgam class I, cusp overlay amalgam class II, and multisurface resin composite class IV restorations were €40, €91, and €65, respectively (base year: 2006; Kelly and Smales, 2004).

Our case vignette described an approximately 12-year-old child, mainly to exclude any complications that might have occurred in the case of older patients. However, some dentists participating in our study pointed out that 12-year-old children usually do not need a filling, as children lose their milk teeth between the ages of 10 and 12. These dentists argued that milk teeth are typically removed as a preferred treatment, and that adult teeth rarely show cavities in this age group because they are relatively new. Furthermore, dental problems in 12-year-old children are rare in Denmark due to the free preventive dental care that is offered to children up to the age of 18. Nevertheless, earlier studies have demonstrated that 12-year-old and even younger children can very well have fillings (Guelmann and Mjor, 2002; Honkala *et al*., 2002; Pair *et al*., 2004; Tran and Messer, 2003).

Other limitations of our study are due to methodological issues. Firstly, although special attention was paid to selecting representative practices in the participating countries, our study reflects the results of only a small number of practices. Secondly, the extent of the cavity was not specified in the vignette, thus ignoring the possibility that longer treatment times might be required to restore an occlusal cavity as compared with cavities affecting two or more surfaces around the tooth. Thirdly, cost information was difficult to obtain, as dentists generally do not record costs per item. As a result, for some practices it was necessary to rely on estimates rather than concrete data. In some cases imputation was used. Another difficulty occurred in collecting overhead costs since the method for allocation of overhead costs varied somewhat from practice to practice.

In conclusion, the mean total costs of a dental filling in a lower molar of an approximately 12-year-old child ranged from €8 to €156 in the nine European countries participating in this study. Labour was by far the most important cost driver. Actual differences in costs between countries were primarily due to differences in unit costs and only to a lesser degree to differences in resource use.

DOI: 10.1002/hec

ACKNOWLEDGEMENTS

The results presented in this article are based on the project 'Health Benefits and Service Costs in Europe – *Health*BASKET', which was funded by the European Commission within the Sixth Framework Research Programme (grant no. SP21-CT-2004-501588).

CONFLICT OF INTEREST

No conflicts of interest declared.

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DOI: 10.1002/hec