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Orthognathic treatment: how much does it cost?

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SUMMARY The aim of this multi-centre retrospective study was to assess the cost, and factors influencing the cost, of combined orthodontic and surgical treatment for dentofacial deformity. The sample, from the south-west of England, comprised 352 subjects (109 males and 243 females) with an age range of 14 to 57 years treated in 11 hospital orthodontic units. Treatment costs were calculated for each subject by combining consumable costs with staff overhead and capital costs.

The median total treatment cost was €6075.25 (interquartile range: €5139.41–€7069.68). Out-patient costs comprised 43 per cent. The median orthodontic treatment costs were €1456.23 (interquartile range: €1283.73–€1638.75). Orthodontic costs on average comprised 25 per cent of the total treatment cost. The cost of orthodontics for orthognathic patients in a hospital setting appears to represent excellent value for the state funded National Health Service in the United Kingdom.

Introduction

The delivery of orthodontic care in the United Kingdom has altered significantly in the last 10 years. The establishment of specialist lists has helped to identify more than 1000 specialist orthodontists (General Dental Council, 2002). The majority of these are practice-based where they undertake a significant and increasing workload. As a consequence, the National Health Service (NHS) expenditure on orthodontics has almost doubled to over €116 million per year over a relatively short period (Department of Health, 2000). Inevitably, there are other shifts in service delivery and, for orthodontic consultants who are hospital based, these have been significant for two reasons. First, the move towards centralization of services for children born with a cleft or a severe craniofacial anomaly has meant that for some consultants there is now less involvement with these children. Second, there is good preliminary evidence that with an increasing workload being undertaken by specialist practitioners, referrals to hospitals are more complex. This includes cases that need joint management and treatment by oral and maxillofacial surgeons and orthodontists (Russell *et al.*, 1999). Combined orthodontic and surgical treatment aims to improve the quality of life for patients who have a dentofacial deformity at the extreme ends of malocclusions. Treatment does not necessarily improve the physical health of the patient and the use of resources for the purposes of orthognathic surgery may prevent use of resources for other procedures for which the health gains are more obvious. It is therefore justifiable to ask questions about the costs, affordability, need, want, and effects of orthognathic surgery. In order to answer these questions, economic evaluations that assess the cost, efficacy, efficiency, and availability of orthognathic treatment, need to be undertaken. These in turn will ultimately aid distribution of resources to provide the greatest benefit to the population (Forbes and Donaldson, 1987).

There are few costing studies on orthognathic care and the majority have investigated costs for surgical procedures in isolation, without considering orthodontic direct, or indirect costs (Lombardo *et al.*, 1994; Dolan and White, 1996; Blakey and White, 1999). Cunningham and Hunt (2000) compared health state utilities for dentofacial deformity derived from orthognathic patients and members of the public. The utility value of dentofacial deformity was similar to the utility value of 'physical and role limitation with occasional pain'. It was not considered as severe a problem as renal dialysis, being anxious or lonely much of the time, or being blind deaf or dumb (using the time trade off method). These results help to rank dento-facial deformity and aid comparison with other health states. The findings from that study have the potential to be combined with costing data from patients who have undergone orthognathic treatment for their dentofacial deformity, in order to derive a cost for each quality-adjusted life year gained.

Some attempts to quantify costs of orthognathic procedures have been undertaken. As an example, Lombardo *et al.* (1994) identified the costs of Le Fort I and bilateral sagittal split osteotomies, albeit in isolation. Average patient charges ranged from $4778 to $8816 for bimaxillary osteotomies, $3538 to $6784 for Le Fort I osteotomies, and $3086 to $5023 for bilateral sagittal split osteotomies. Bimaxillary surgery was therefore associated with the highest hospital charges and mandibular surgery with the lowest. The surgery-related costs in that study seem to be substantial, but it must be emphasized that the figures quoted are patient charges and may not reflect the true cost

of providing treatment. It seems therefore that surgical costs greatly influence the cost of treatment for patients with dentofacial deformity. However, the out-patient costs which relate to orthodontic treatment should not be underestimated. Orthodontic treatment often involves short out-patient visits to a single clinician and requires a variety and number of support staff. Orthodontic consumables are inexpensive when compared with those used in operating theatres, but frequent visits over a long time period are required. Orthodontic costs per visit are low, but the large number of appointments during treatment will increase costs. They may comprise a substantial proportion of the total cost of orthognathic treatment and there is currently a lack of information on the orthodontic costs in relation to the total cost of orthognathic care. The aim of this study was to perform a cost-description analysis and calculate the direct health service costs relating to orthognathic treatment.

Subjects and materials

Identification of subjects

Orthodontic consultants were asked to identify patients who underwent orthognathic surgery to correct their dento-facial deformity. The treatment had to have involved both orthodontics and surgery and the latter to have been performed between 1 January 1995 and 31 March 2000. Subjects were excluded if their dentofacial deformity was associated with orofacial clefting or with a recognized orofacial syndrome. They were also excluded if they were transferred or their treatment had started elsewhere. Four hundred and eighty nine subjects were originally identified from 11 hospital units in the South West Region. One hundred and thirty seven subjects were subsequently excluded principally because their surgery dates were outside the limits set.

Out-patient clinics

To quantify out-patient costs, the following were recorded: the number of pre-treatment, routine treatment, and post-treatment reviews, orthodontic emergency and 'did not attend' (DNA) appointments before and after debonding of orthodontic appliances, as well as pre- and post-surgery appointments; the number of joint clinic appointments where subjects were seen jointly by orthodontic and surgical clinicians.

Consumables

Consumables were identified as being any product or item whose use during treatment invoked a cost due to recycling or replacement. These included replaceable items such as radiographs, gloves, information leaflets, cements, and orthodontic brackets as well as items which could be recycled, such as instruments. The costs, excluding value added tax, were included at 6 April 2000 to 5 April 2001 tax year levels. Lists of consumables were compiled for the various out-patient appointments. The sterilization costs for instrument trays and individually packed instruments were obtained from the central sterilization department and included an amount for 'wear and tear'. Many consumables, such as orthodontic modules, archwires, cotton wool rolls, and mouthwash tablets, are supplied in bulk and therefore costs of individual items were calculated. For example, a bag of orthodontic modules cost €34.83. Each bag contains on average 46 strips of modules with each strip comprising 22 individual modules. Each module therefore costs €0.035. This figure was subsequently multiplied by the average number of bracketed teeth to establish the cost of changing modules during routine orthodontic visits.

Costs of consumables such as cements or impression materials, where a single item could be used for a number of patients, were calculated according to the number of impressions taken or bands cemented using a standard bag or bottle. For example, a 500 g bag of alginate impression material costs €8.58. Each scoop of alginate weighs 7.5 g (average of three weightings) and on average three scoops are used per impression. Each bag of impression material could therefore provide for approximately 22 impressions at a cost of €0.39 each. The average number of impressions taken was established from data collected on the numbers of study and articulated models produced and was used to calculate an average cost of alginate for subjects. This gives some insight as to how the detail on costs was collected.

Laboratory costs

Laboratory costs were obtained for the production of items such as study models, retainers, and surgical wafers. These costs were based on average commercial prices (average of a high, middle, and low quote). As commercial laboratories infrequently construct (and therefore price) surgical wafers, the cost of these items were estimated from the time taken to construct wafers. These timings were obtained from the orthodontic laboratory at one hospital unit.

Consumables

The use of consumables is bound to vary with individual operators and, to produce an average figure, a subset of 20 hospital records was examined to establish the quantity of consumables used per subject during out-patient appointments and surgery.

The number of study models, orthodontic brackets, bands, and wires (including type) were determined from the hospital notes. The mean number of consumables used was calculated and this information established orthodontic bracket, band, archwire, and surgical fixation costs.

Capital and overhead costs

Departmental capital and overhead costs for orthodontic, oral, and maxillofacial surgery and theatres were obtained from the finance division of the same hospital unit used to establish consumable costs. Capital costs for out-patient departments and theatres were based on the total capital expenditure of that hospital. The standard method of using the floor area occupied by each department was used to apportion capital costs to each department. Overhead expenses (e.g. lighting and heating facilities) were calculated from departmental itemized budget statements and the total hospital expenditure on overheads.

Staff costs

Staff cost calculations for clinicians were based on the operator grades. Data were collected to establish numbers and grades of staff present in out-patient clinics and theatres other than the main clinician. In addition, the duration in minutes of each type of out-patient appointment such as those for orthodontic treatment, post-debond reviews, joint clinics, and preparation for surgical wafers was recorded. This information was collected from each hospital unit. The mean numbers of each grade of staff member and mean out-patient appointment durations were subsequently calculated from the data. National pay scales were used to calculate per minute staff costs and the mean salary inclusive of superannuation and national insurance contributions. These staff costs per minute were then combined with overheads and capital costs per minute from each out-patient department (orthodontics or other specialities) to provide staff overheads and capital costs per minute. The cost per appointment was derived by multiplying the staff overheads and capital costs per minute by the average duration of each appointment type. This figure was then multiplied by the total number of appointments in each area to obtain the total staff overheads and capital costs of each appointment type. This method was used for the calculation of costs for various clinic appointments. Calculations took into account the fact that some appointments were longer than others and thus incurred higher staff overheads and capital costs.

Error study

To establish an error for the method of data collection, 10 sets of hospital records were randomly selected and reassessed by one examiner (SK). Errors in the calculations were determined by asking a different researcher to recalculate the formulae and results, which were then compared with those originally produced. The errors were minimal and less than 1 per cent.

Results

The total treatment costs were calculated for 352 subjects (109 males and 243 females). Their ages ranged from 14 to 57 years. The average total cost for the tax year running from 6 April 2000 to 5 April 2001 was €6293.72. Costs ranged from €3796.66 to €12 010.03. A Kolmogorov–Smirnov normality test was performed which showed that the distribution of costs differed significantly from a normal distribution ($P < 0.001$). Figure 1 highlights the skewed nature of the costs. The median total treatment cost was €6075.25 with an interquartile range of €5139.41–€7069.68.

Out-patient costs were established for all 352 subjects. The average routine orthodontic treatment cost was €1496.79 per subject. The average cost of orthodontic emergency appointments was €80.12 per subject, DNA appointments €50.85 per subject, joint clinic costs €632.61, and the average cost of appointments in other specialities, such as maxillofacial surgery, €156.57 per subject. Average laboratory costs were €269.18 (Table 1).

Costs for individual out-patient visits

Descriptive statistics for out-patient costs per visit are shown in Table 2. Routine orthodontic costs, on average, comprised 25 per cent of the total treatment cost. This figure excluded the cost of emergency and DNA appointments. The latter each comprised 1 per cent of the total cost. Joint clinic costs comprised, on average, 10 per cent of the total cost, whereas appointments in other specialities, apart from orthodontics comprised 2 per cent of total costs. Laboratory costs comprised 4 per cent of the total cost.

Routine orthodontic treatment costs

The average staff overhead and capital costs for routine orthodontic appointments amounted to €974.70 per subject.

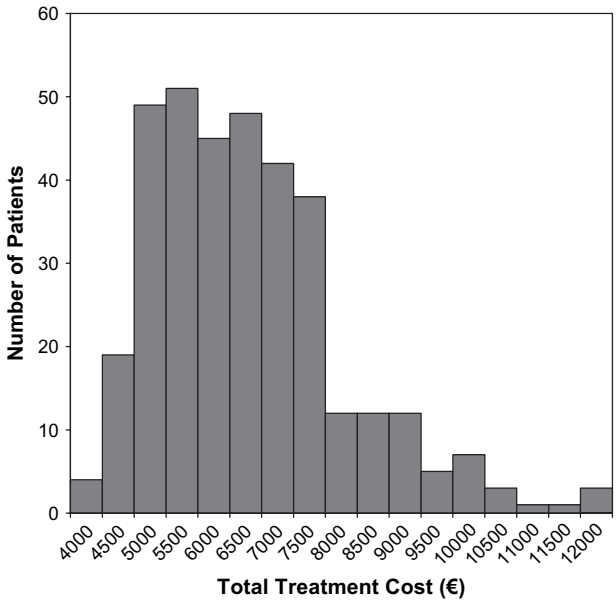

Figure 1 Graph showing the skewed distribution of total treatment cost for 352 subjects.

Table 1 Descriptive statistics of treatment costs per subject in different out-patient settings.

	Routine orthodontics (€)	Joint clinic (€)	Orthodontic emergency (€)	Did not attend (€)	Laboratory (€)	Other specialities (€)
Number of subjects	352	352	352	352	352	352
Median	1453.55	641.20	53.05	33.65	300.64	139.85
Minimum	877.17	00.00	00.00	00.00	84.94	00.00
Maximum	2773.21	1920.42	955.04	403.77	403.23	1071.23
Range	1896.04	1920.42	955.04	403.77	318.29	1071.23
Interquartile range	1281.37–1635.53	480.09–800.15	00.00–106.07	00.00–67.29	219.76–362.60	46.58–233.00

Table 2 Descriptive statistics of cost per visit for different out-patient appointments.

	Routine orthodontics (€)	Joint clinic (€)	Orthodontic emergency (€)	Did not attend (€)	Other specialities (€)
Number of subjects	352	349	234	204	277
Median	55.11	160.00	53.05	33.65	46.59
Minimum	34.20	160.00	40.46	21.03	46.59
Maximum	86.81	160.00	53.05	33.65	46.59
Range	52.61	00.00	12.59	12.62	00.00
Interquartile range	54.88–60.18	160.00–160.00	53.05–53.05	33.65–33.65	46.59–46.59

Consumable costs (including radiographs) were on average €522.51 per subject. The relative contributions of consumables and staff overhead and capital costs are shown in Table 3. Staff overhead and capital costs comprised 65 per cent of routine orthodontic costs and consumables 35 per cent. In view of the overall skewed distribution of costs, a Wilcoxon signed-rank test was performed. There were significant differences between staff overheads, capital costs, and consumable costs ($P < 0.001$).

Comparison of out-patient, in-patient, and operating theatre cost

For the 352 subjects in the study, the average total cost of treatment in out-patient departments was €2690.15 (Table 4). The average cost in the operating theatres was €2168.51 and in-patient costs were €1441.84. The in-patient costs included those for the intensive care unit and the ward stay. Using the Wilcoxon signed-rank test to assess differences, out-patient treatment costs were found to be significantly higher than operating theatre costs ($P < 0.001$).

Table 3 The contribution of staff capital and overhead and consumable costs to routine orthodontic appointment costs. All 352 subjects are included. Total routine orthodontic treatment costs are obtained by combining orthodontic staff overhead and capital costs with consumable costs.

	Staff overhead and capital cost, A (€)	Consumable cost, B (€)	Total cost of routine orthodontic treatment, A + B (€)
Median	944.88	508.67	1453.55
Minimum	458.64	418.53	877.17
Maximum	2078.52	694.69	2773.21
Range	1619.88	276.16	1896.04
Interquartile range	797.83–1102.01	483.54–533.52	1281.37–1635.53

Influence of gender on costs

The average total treatment cost was €6294.49 for males and €6305.58 for females (Table 5). The total cost of joint clinic appointments was significantly higher for females ($P = 0.037$), whereas the total cost of DNA appointments was significantly higher for males ($P = 0.009$).

Influence of age on cost

Subject age at the time of surgery ranged from 14 to 57 years. The 352 subjects were stratified into two age ranges. The first range comprised 183 subjects aged 19 years and below and the second 169 subjects aged 20 years and above. On average, the total treatment cost was €6471.34 for subjects aged 20 years and above. The cost was €6156.40 for subjects aged 19 years and below. Total treatment cost was significantly higher in the 20 years and above range ($P = 0.032$). Significant differences were also found in the total costs for routine orthodontic appointments ($P = 0.034$), joint clinic appointments ($P = 0.001$), emergency appointments ($P = 0.022$), and appointments in other specialities ($P < 0.001$). There were also borderline differences in laboratory costs ($P = 0.030$) and total operating theatre costs ($P = 0.046$). Apart from routine orthodontic costs, all these costs were significantly higher in the 20 years and above age range (Table 6).

Table 4 Descriptive statistics of out-patient, in-patient, and operating theatre costs for 352 subjects.

	Total out-patient cost (€)	Total in-patient cost (€)	Total operating theatre cost (€)
Median	2631.37	1253.68	2073.38
Minimum	1394.69	501.48	893.79
Maximum	5001.75	6126.14	4528.13
Range	3607.06	5624.66	3634.34
Interquartile range	2337.14–2996.99	1003.12–1504.67	1518.97–2695.57

Influence of start malocclusion on cost

The influence of the start malocclusion on cost was determined by separating malocclusion into antero-posterior and vertical relationship categories.

Antero-posterior relationships

Eleven subjects had a Class I malocclusion, 188 a Class II malocclusion, and 153 a Class III malocclusion. The average total treatment cost for subjects with a Class I malocclusion was €6484.64, Class II €6060.44, and Class III €6584.40. The Kruskal–Wallis test was used to assess differences in costs between all three malocclusion groups as a whole (Table 7). As the subjects were categorized into three classes of antero-posterior malocclusion, the Mann–Whitney *U*-test was also used to assess cost differences between pairs of malocclusion Class. Differences were found in total cost for routine orthodontic treatment appointments ($P = 0.009$), appointments in other specialities ($P = 0.007$), and operating theatres ($P < 0.001$).

Total treatment costs for patients with a Class III malocclusion were significantly higher than those for subjects with a Class II malocclusion ($P = 0.02$). The total routine orthodontic treatment cost was highest for subjects with Class II malocclusions. Costs for the other classes were significantly lower ($P = 0.018$ and 0.030 for Classes I and III, respectively). Interestingly, using the Mann–Whitney *U*-test, the highest total cost of appointments in other departments was for subjects with Class I malocclusions. This was significantly higher than the costs for those with Class II ($P = 0.002$) and Class III ($P = 0.003$) malocclusions. There was no significant difference between the cost of appointments in other specialities for subjects with Class II and Class III malocclusions. Laboratory costs were significantly higher for subjects with Class III malocclusions than for those with Class II and I malocclusions ($P = 0.002$ and $P = 0.039$, respectively).

Vertical relationships

The subjects were divided into groups, according to whether they had a normal overbite, deep overbite, or an anterior open bite (AOB). Two hundred and seventy six subjects had a normal overbite, 53 an AOB, and 23 a deep overbite. The

Table 5 The influence of gender on total treatment and selected out-patient costs.

	Cost in €, median (range)		Mann–Whitney *U*-test
	Male, $n = 109$	Female, $n = 243$	*P* value
Joint clinic appointment	480.44 (00.00–1601.48)	641.20 (00.00–1921.97)	0.037
Did not attend	33.65 (00.00–404.25)	33.65 (00.00–370.56)	0.009
Total treatment cost	6199.43 (4032.94–7967.00)	6036.61 (3796.66–7904.83)	0.858

Table 6 Cost differences between the two age range groups. Out-patient, in-patient, and operating theatre costs are shown.

	Cost in €, median (range)		Mann–Whitney *U*-test
	Age range 19 years and below, $n = 183$	Age range 20 years and above $n = 169$	*P* value
Routine orthodontic appointments	1487.76 (942.33–2758.38)	1424.90 (878.19–2776.66)	0.034
Joint clinic appointments	480.65 (00.00–1441.97)	641.20 (00.00–1922.59)	0.001
Emergency appointments	53.05 (00.00–452.91)	53.05 (00.00–955.89)	0.022
Did not attend	33.65 (00.00–404.10)	33.65 (00.00–370.43)	0.650
Laboratory	290.64 (85.02–393.56)	300.64 (95.19–403.72)	0.030
Other specialities	93.27 (00.00–699.27)	139.85 (00.00–1072.21)	<0.001
Total treatment cost	5929.28 (3796.66–11 808.13)	6208.43 (3987.88–12 008.14)	0.032

Table 7 Differences in cost according to the class of antero-posterior malocclusion. Costs for out-patient, in-patient, and operating theatre settings are shown.

	Cost in €, median (range)			Kruskal–Wallis *H*-test
	Class I, *n* = 11	Class II, *n* = 188	Class III, *n* = 153	*P* value
Routine orthodontic appointments	1194.55 (878.78–1916.62)	1505.95 (998.45–2760.00)	1436.93 (938.74–2778.10)	0.009
Joint clinic appointments	320.59 (00.00–1923.59)	641.20 (00.00–1282.39)	641.20 (160.29–1602.90)	0.313
Emergency appointments	42.23 (00.00–253.51)	53.05 (00.00–956.77)	53.05 (00.00–380.25)	0.253
Did not attend	33.65 (00.00–235.92)	33.65 (00.00–303.32)	33.65 (00.00–404.42)	0.343
Laboratory	155.51 (95.23–393.78)	290.64 (85.09–404.01)	313.13 (85.09–393.78)	0.002
Total treatment cost	5871.20 (4063.55–9681.66)	5779.65 (3863.77–10 416.03)	6344.39 (3796.66–12 010.03)	0.002

average total treatment cost for subjects with a normal overbite was €6304.44. Subjects with an AOB had an average total treatment cost of €6593.33, whereas those with a deep overbite had a cost of €5580.71. The Kruskal–Wallis test was used to assess differences in costs between the three vertical malocclusion groups as a whole (Table 8). The Mann–Whitney *U*-test was used to assess cost differences between pairs of malocclusion type. Significant differences were found between the vertical malocclusion groups as a whole for total treatment cost ($P = 0.007$). The total treatment cost for subjects with a normal overbite or an AOB was significantly higher than that for those with a deep bite ($P = 0.002$ and $P = 0.009$, respectively).

Influence of operator grade

Two hundred and eighty five subjects had their orthodontic treatment performed by a consultant, and 67 by other grades. Average total treatment costs were €6373.31 for subjects whose orthodontic treatment was performed by a consultant and €5992.37 for subjects treated by non-consultant grades. Average total routine orthodontic treatment costs were €1562.11 and €1233.21, respectively (Table 9). The total cost of routine orthodontic treatment was significantly higher for subjects treated by a consultant orthodontist ($P < 0.001$), and similarly, the total cost of appointments in specialities apart from orthodontics was higher for subjects treated by a consultant ($P < 0.001$). For consultant and non-consultant grades, there was no significant difference in the number of routine orthodontic appointments attended by the patients.

Regression analysis

A linear regression analysis using a forward selection method was performed. Total treatment cost was used as the dependent variable and original data collected from the subjects' hospital records, used originally to calculate treatment costs, as the independent variables. During the analysis, the independent variables were added such that the most significant predictor of the dependent variable was added first. The different models show the independent variable added during the analysis. The regression analysis revealed seven factors that explained 95 per cent of the variation in total treatment cost. The most influential factors were operation duration; the number of routine orthodontic appointments explained only 3.5 per cent.

Model 1	Operation duration (minutes)
Model 2	Model 1 + number of days in intensive care unit
Model 3	Model 2 + number of days on ward
Model 4	Model 3 + total number of joint clinic appointments

Table 8 Differences in cost according to the type of vertical malocclusion. Costs for out-patient, in-patient, and operating theatre settings are shown.

	Cost in €, median (range)			Kruskal–Wallis *H*-test
	Normal, *n* = 276	Anterior open bite, *n* = 53	Deep bite, *n* = 23	*P* value
Routine orthodontic appointments	1453.55 (937.98–2775.86)	1459.47 (877.88–2131.65)	1450.25 (1228.03–2200.92)	0.869
Joint clinic appointments	641.20 (00.00–1922.48)	641.20 (00.00–1762.09)	480.57 (320.39–961.15)	0.771
Emergency appointments	53.05 (00.00–478.04)	53.05 (00.00–956.07)	53.05 (00.00–478.04)	0.840
Did not attend	33.65 (00.00–404.57)	33.65 (00.00–236.00)	22.81 (00.00–269.71)	0.694
Laboratory	300.64 (85.10–404.06)	300.64 (95.27–393.88)	240.58 (95.27–393.88)	0.024
Total treatment cost	6071.91 (3796.66–12 010.03)	6262.05 (4067.26–9926.74)	5147.23 (3987.30–9006.55)	0.007

Table 9 A comparison of costs for subjects treated by consultant and non-consultant orthodontists. A selection of out-patient costs and total treatment cost are shown.

	Cost in €, median (range)		Mann–Whitney *U*-test
	Consultant, *n* = 285	Non-consultant, *n* = 67	*P* value
Routine orthodontic appointments	1511.69 (943.04–2778.54)	1208.42 (878.79–1561.58)	<0.001
Joint clinic appointments	641.20 (00.00–1763.35)	641.20 (160.31–1923.65)	0.098
Emergency appointments	53.05 (00.00–956.40)	42.23 (00.00–453.12)	0.491
Did not attend	33.65 (00.00–404.53)	22.81 (00.00–205.30)	0.326
Appointments in other specialities	93.36 (00.00–653.55)	186.73 (00.00–1073.69)	<0.001
Total treatment cost	6117.92 (3793.54–12 010.03)	5886.23 (3868.40–8732.59)	0.212

Model 5 Model 4 + total number of routine orthodontic appointments
Model 6 Model 5 + type of surgery performed (single jaw or bimaxillary surgery)
Model 7 Model 6 + number of appointments in other specialities

Discussion

The primary aim of this study was to establish the direct health service costs of combined orthodontic and surgical treatment for the correction of dentofacial deformity. The method of deriving direct health service costs was based on established economic concepts, with all costs being measured from one hospital unit (Robinson, 1993; Sculpher *et al.*, 1993; Kendall *et al.*, 2000). A micro-costing approach was used to derive costs in out-patient and operating theatre settings, with a separate assessment of staff, capital, overhead, and consumables expenditure (Drummond *et al.*, 1997). A number of aspects of the investigation may have influenced the accuracy of the treatment costs.

The study was retrospective and heavily reliant on the accuracy of data held in the hospital records of each subject. Data were also used which were not specific to the individual subjects in the investigation and may therefore have reduced the accuracy of costs calculated for individuals. Prospective evaluation is considered superior to retrospective evaluation of treatment costs since it allows direct assessment of staff, overheads, capital, and consumables resource usage (Drummond *et al.*, 1997). This latter method is, however, labour intensive and expensive. In addition, as joint orthodontic and surgical treatment takes an average of 30 months to complete, the data would need to be collected over a long period of time. The present study was based on a large sample of 352 patients which offsets some of the disadvantages of a retrospective study design.

Calculation of staff costs

All staff costs were based on the mean of the appropriate salary scale. They were also adjusted to account for employer costs such as national insurance contributions and pension payments. This was similar to the methods used by Sculpher *et al.* (1993).

Out-patient costs

In this study, out-patient costs included the cost of orthodontic appointments, joint clinic appointments, and appointments in other specialities. They comprised, on average, 43 per cent of the total treatment cost. In-patient costs comprised 22 per cent and operating theatre costs 35 per cent of the total cost, respectively. There are no published studies that compare out-patient costs to operating theatre and in-patient costs for patients undergoing joint orthodontic and surgical treatment for dentofacial deformity. The results from this study clearly show that out-patient costs are important in the total treatment cost. However, the latter costs are derived from 2 years of attendance, whereas the operating costs are 35 per cent for 3–4 hours of surgery. Routine orthodontic treatment appointments alone accounted for 25 per cent of the total treatment cost, forming the bulk of the out-patient costs. These may be the focus of any attempt to reduce out-patient costs but further studies are required in order to assess costs in relation to outcomes. Joint clinic costs comprised 10 per cent of the total treatment cost but these are important fora in which patients, their relatives, orthodontists, surgeons, and other clinicians can discuss, plan, and review treatment. The increased number of clinical staff present during joint clinics reflects in their high total cost and further studies on cost and outcome may also help to assess the relative merits of these clinics. The total cost of emergency and DNA appointments was found to be low, with each comprising 1 per cent of total treatment cost. This is encouraging, and indicates that patients who undergo joint orthodontic surgical treatment are, in general, well motivated and compliant.

The Chartered Institute of Public Finance and Accounting (CIPFA, 2000) published hospital expenditure figures for the year 1999–2000. Using these figures, each out-patient appointment in the dental specialities was calculated to cost €92.43. In the present study, the cost per appointment varied according to the setting. For example, the median cost for each routine orthodontic appointment was €55.11. For

appointments in other specialities it was €46.59 and for emergency orthodontic appointments €53.05. Apart from the cost per joint clinic appointment, all out-patient costs were lower than the appointment cost published by the CIPFA. If the CIPFA figures had been used for calculating out-patient costs in this study, the costs would have been an overestimation. More accurate micro-costing might help CIPFA produce more relevant figures to inform Government spending.

Factors influencing cost

The final aim of the study was to assess factors that influence the cost of combined orthodontic and surgical treatment for the correction of dentofacial deformity. It was found that subjects aged 20 years and above had higher total treatment costs and these were higher in all cost settings, apart from total routine orthodontic costs. These higher costs may relate to medical history issues or slower post-surgical recovery in older patients. In addition, older patients tend to ask more questions and are more demanding of full explanations. The reduced orthodontic costs in older subjects may result from better compliance. Others have found that age and gender have no influence on the duration of the orthodontic treatment related to orthognathic surgery (Wieber *et al.*, 1999).

The original malocclusion

The antero-posterior and vertical pattern of a malocclusion was found to affect the cost of treatment. The total treatment cost for subjects with a Class III malocclusion was significantly higher than that for those with a Class II malocclusion. In addition, the total treatment cost for subjects with an AOB was significantly higher than for those with a deep overbite. The reasons for the differences in cost for the vertical pattern of malocclusion may lie in the type of surgery performed. AOBs are often treated using bimaxillary or maxillary surgery only. However, malocclusions with a deep overbite can often be treated successfully with mandibular surgery alone (Proffit *et al.*, 1996). As bimaxillary and maxillary-only surgery are associated with higher costs, it follows that the treatment of AOBs may be more expensive than for deep bite malocclusions. Differences in cost between Class III and Class II probably relate to the fact that 64 per cent of the subjects with a Class III malocclusion had bimaxillary surgery compared with 31 per cent of subjects with a Class II malocclusion.

The grade of orthodontic operator

The total cost of routine orthodontic appointments was significantly higher for subjects treated by a consultant orthodontist than by non-consultant grades. Analysis of the data revealed that there was no significant difference in the number of routine orthodontic appointments attended by subjects for consultant and non-consultant grades. This suggests that the orthodontist's salary was the most important factor influencing the cost.

The prospective study by Jackson and Beun (2000) on the cost and outcome of treatment of chalazion (eye cysts) provides useful information on the influence of salary. This study found that senior nursing staff could provide treatment at a lower cost than senior house officers. The nurses in the study had a higher salary than senior house officers and the cost of each patient's appointment was subsequently higher. However, treatment provided by a senior nurse was more cost-effective. This was because patients were less likely to return for a further visit, being more likely to receive conservative treatment. The outcomes of treatment were similar for both nurses and senior house officers. It was concluded that by treating larger numbers of patients, nurses were more skilled in deciding which cysts responded to conservative therapy and which required enucleation. The findings of the present study suggest that the costs, although interesting, are of limited value in isolation. Any future comparison of costs for consultant- and non-consultant-treated subjects can only be made when combined with an evaluation of quality of outcome.

Conclusions

Overall, this micro-costing exercise demonstrated that orthodontics for orthognathic subjects in the state funded health service in the United Kingdom is inexpensive. Although the effectiveness of orthodontic care was not considered in this study, it is a further measure that is needed. The figures for the overall cost of treatment consolidate those reported by Richmond *et al.* (2004) where, within a variety of settings within the NHS in the United Kingdom, costs averaged between €760 and €1303 per patient for a course of treatment. In the current study, the average cost of orthodontics for orthognathic cases in a hospital setting was €1497 which, considering the complexity of treatment, seems to represent a very inexpensive service. The cost to the patient was not scrutinized but represents another variable which should be included in any future research to determine the true cost-effectiveness of treatment.

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