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D5.2 Completion of cost analysis of CBCT

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Abstract:

Objective: The objective was to analyse the costs of Cone Beam Computed Tomography (CBCT) examinations for three different clinical situations, in four radiological clinics in four different countries: Cluj-Napoca (Romania), Leuven (Belgium), Malmö (Sweden) and Vilnius (Lithuania).

Material and Method: Model protocols that were established earlier were used to identify costs for CBCT examinations. The examinations were performed on patients with the following three different clinical situations: (1) maxillary canines with eruption disturbances, (2) lower wisdom teeth and (3) patients in need of implant treatment. The cost analysis was based on actual costs that were subdivided according to the categories 'direct costs' (capital cost for equipment and accommodation and labour cost) and 'indirect costs' (patients' and accompanying persons' time spent on travel and examination and 'out of pocket' costs).

Results: The mean of direct cost per examination for the three different clinical situations using CBCT as diagnostic imaging method was highest in Malmö with 85.32€, followed by Vilnius with 52.58€. The corresponding figure for Cluj was 26.98€ and for Leuven 18.75€. The indirect costs were also highest in Malmö with a mean for the three clinical situations of 93.14€, followed by Cluj with 63.31€, Vilnius 32.22€ and Leuven with a mean of 20.29€.

Conclusion: The estimates of the costs of using CBCT as a diagnostic method for the three different clinical situations (retained canines, implant treatment planning and lower wisdom teeth) vary considerably between the four country settings studied. There is no clear association between the estimated costs and the economic wellbeing of the country as measured by GDP per capita. The report discusses the factors contributing to the differences between the country settings.

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1. The Context

1.1 SEDENTEXCT Aims and objectives

The aim of this project is the acquisition of the key information necessary for sound and scientifically based clinical use of dental Cone Beam Computed Tomography (CBCT). In order that safety and efficacy are assured and enhanced in the 'real world', the parallel aim is to use the information to develop evidence-based guidelines dealing with justification, optimisation and referral criteria and to provide a means of dissemination and training for users of CBCT. The objectives and methodology of the collaborative project are:

1. To develop evidence-based guidelines on use of CBCT in dentistry, including referral criteria, quality assurance guidelines and optimisation strategies. Guideline development will use systematic review and established methodology, involving stakeholder input.

2. To determine the level of patient dose in dental CBCT, paying special attention to paediatric dosimetry, and personnel dose.

3. To perform diagnostic accuracy studies for CBCT for key clinical applications in dentistry by use of in vitro and clinical studies.

4. To develop a quality assurance programme, including a tool/tools for quality assurance work (including a marketable quality assurance phantom) and to define exposure protocols for specific clinical applications.

5. To measure cost-effectiveness of important clinical uses of CBCT compared with traditional methods.

6. To conduct valorisation, including dissemination and training, activities via an 'open access' website.

At all points, stakeholder involvement will be intrinsic to study design.

1.2 Work package 5 (WP5) objectives

The main objective of Work Package 5 Task 1 is to analyse the cost-effectiveness of CBCT in different clinical situations, health care contexts and countries. Task 2 aims to analyse the additional therapeutic efficacy of CBCT for selected clinical situations.

1.3 Deliverable D5.2

Deliverable D5.2 reports the completion of the work in Task 1 concerning cost analysis of CBCT, earlier work having been reported in deliverable D5.1[1].

[1] http://www.sedentexct.eu/system/files/sedentexct_deliverables_wp5_d5.1_v1.1.pdf (last accessed 29 September 2010)

1.4 Background to this deliverable

The work originally was intended to include information on cancer-related costs, based on dosimetry from WP2. This was discussed in the SEDENTEXCT consortium meeting in Malmö, Sweden, on 8 January 2010, with the EC Project Officer in attendance[2]. It was agreed that dosimetry-based data was no longer required as the cancer risk is so low that the costs, if any, connected to this risk will have no impact on the calculations in this work package.

Examination with CBCT is currently requested in a number of clinical conditions within oral health care. Information was obtained from SEDENTEXCT partners on the clinical situations for which patients are most frequently referred for CBCT examinations. The most frequent referrals were found to be for (1) patients with retained maxillary canines, (2) patients with lower wisdom teeth that are planned to be extracted, (3) patients with partly edentulous jaws being considered for implant treatment and (4) patients with temporo-mandibular joint disorders.

Originally, the plan for the work in WP5 was to start patient examinations on the four listed clinical situations simultaneously. However, as the development of protocols for analysis of costs was more complicated and time consuming than anticipated, it was decided to start with one key paediatric use of CBCT, namely patients with maxillary canines with eruption disturbances. The cost analysis for this situation has been reported previously[1]. The constructed protocols have since then been used for more patients with maxillary canines and for patients with lower wisdom teeth that are planned to be extracted, and patients with partly edentulous jaws being considered for implant treatment. When the study had been ongoing for a while it became apparent that patients with temporo-mandibular joint disorders were not referred for CBCT examinations to that extent as had been anticipated and patients with this clinical situation were excluded from the study.

[2] www.sedentexct.eu/content/malmo-8-january-2010-minutes (last accessed 29 September 2010)

2. The Methodology

2.1 Patients and examinations

The departments where patient examinations have been performed are connected to the following universities:

- Oral Imaging Centre, Katholieke Universiteit Leuven, Belgium
- Department of Oral and Maxillofacial Radiology, Malmö University, Sweden
- Faculty of Dental Medicine, University of Medicine and Pharmacy in Cluj-Napoca, Romania
- Vilnius University, Vilnius, Lithuania.

Following institutional ethical approval, patients were consecutively examined with CBCT because of either having one or two maxillary canines with eruption disturbances, one or two lower wisdom teeth that were intended for extraction or patients having areas with missing teeth that might be replaced with implants. All patients were referred for CBCT examinations. Patients were asked to participate in the study during March 2009 - March 2010.

Table 1 presents the number of participating patients for each of the three different clinical situations in each of the four countries.

Table 1: Number of participants per clinical situation per site

	Clinical situation					
	Retained canines		Lower wisdom teeth		Implant treatment planning	
Radio-logical clinic	Number of patients	Age	Number of patients	Age	Number of patients	Age
Cluj	20	24 (13-55)	39	48 (30-67)	50	22 (9-36)
Leuven	50	15 (8-37)	46	54 (24-88)	38	29 (15-71)
Malmö	47	14 (10-19)	50	53 (18-83)	47	32 (13-74)
Vilnius	50	22 (9-60)	50	44 (22-68)	50	25 (17-51)

The radiographic equipment used for CBCT were New Tom 3G (QR, Italy) in Cluj, Romania, Scanora (Sorodex, Finland) in Leuven, Belgium, Accuitomo (Morita, Japan) in Malmö, Sweden, and New Tom CVT 9000 (QR, Italy) in Vilnius, Lithuania.

2.2 Cost-analysis

The model for cost-analysis of diagnostic methods, presented in deliverable D5.1 includes three parts:

- identification of different resources used;
- measurement of the amount of each of these resources required;
- valuation of each resource used.

The unit cost per procedure is presented in monetary terms. The model comprises direct costs (the costs incurred by providers in delivering the service) and indirect costs (the costs incurred by patients in using the service) and is based on the method proposed by Drummond et al.[3] Four data collection instruments were designed:

- protocol for apportioning the cost of capital equipment to each procedure
- form for measuring consumable items
- form for measuring the time that different health care providers used for the examinations
- survey for measuring the time and cost for the patients and accompanying persons.

2.2.1. Direct costs

The direct costs cover the cost of capital equipment such as apparatus, computers and digital screens, costs for accommodation, i.e. clinic and office space, as well as the cost for labour in each of the four different clinics.

The cost for the radiographic apparatus is calculated by dividing the purchase costs by the expected lifetime. The cost for accommodation for the clinic and office space is calculated as the cost per square meter and includes services (cleaning, lighting and heating). The clinic and office space is estimated from the construction map of the four different clinics.

The method for valuation of the labour cost per hour is presented in Appendix 1, exemplified by figures from one clinic (Malmö, Sweden). The estimation of working time for radiologists in interpretation of images and writing the radiographic report was based on the time recorded by three specialists interpreting images of retained canines.

The working time associated with the patient was recorded in the survey for indirect costs and includes time for administration, examination and the imaging process. In Cluj and Vilnius, the specialists perform the examinations and the imaging process, while in Leuven and Malmö, this is done by the radiographers and dental assistants, respectively.

To obtain the cost per examination, the different costs for equipment, accommodation and labour, respectively, are divided by the number of images taken during a year. This cost per image is then multiplied by the number of images taken per examination.

[3] Drummond MF, Sculpher MJ, Torrance GW, O´Brien BJ, Stoddart GL. Methods for the economic evaluation of health care programmes 3: rd ed. Oxford: Oxford Univ. Press, 2005.

2.2.2. Indirect costs

The indirect costs include a valuation of the time spent by patients and accompanying persons on travel, waiting and undergoing the examination as well as the fee cost. These data are collected and measured with the aid of a survey (see deliverable D5.1).

Time spent by the patients and accompanying persons is valued according to the national average wage cost per hour[4]. The time spent by patients under the age of 18 was valued according to the minimum wage[5]. If the patients came directly from another clinic to the radiology clinic the time and expenditure spent on travel was valued to zero.

The examination fee is the fee paid directly by the patient and/or the accompanying person.

[4] e.g. Sweden: Statistics Sweden [Internet]. Consumer Price Index (CPI). [Updated 2010 July 5; cited 2010 March 5]. Available from: http://www.scb.se/Pages/TableAndChart___28319.aspx (last accessed 29 September 2010).

[5] e.g. Sweden: Skedinger P. Hur höga är minimilönerna? The Institute for Labour Market Policy Evaluation, IFAU 2004. Rapport 2005:18 IFAU, p 28.

3. Results

3.1 Cost analysis

The mean values for total cost per examination, based on calculations of costs for the three clinical situations with CBCT was highest in Malmö with 178.46€ , and the lowest in Leuven 39.04€. In Cluj the cost per examination was 90.29 4€ and in Vilnius 84.80€ (Appendix 2).

3.1.1 Direct costs

The total direct costs, calculated as a mean for the three clinical situations, are presented in Appendix 2. The direct costs in Malmö and Vilnius were relatively high with 85.32€ and 52.58€ respectively, reflecting the relatively high purchase cost for the CBCT machine and large office and clinic space. The direct costs per examination in Cluj and Leuven were estimated to 26.98€ and 18.75€ respectively.

The *capital* cost for equipment in Vilnius was the most expensive, 226 828.99€ and least expensive in Cluj, 147 878.54€. The purchase years were 2002 and 2006, respectively. The cost per examination, based on capital cost for equipment, is 25.28€ in Cluj, 10.67€ in Leuven, 58.94€ in Malmö and 50.18€ in Vilnius (Appendix 2).

The cost per square-meter in Cluj is 30.49€, in Leuven 400€, in Malmö 215€ and 20.29€ in Vilnius. This resulted in a cost for *accommodation* per examination of 1.29€ in Cluj, 1.60€ in Leuven, 17.21€ in Malmö and 1.64€ in Vilnius (Appendix 2).

A sample calculation of *labour* cost and working time for the radiologists and dental assistants in one centre (Malmö, Sweden) can be seen in Appendix 1.

The average working time for a radiologist for interpretation of images and writing the report was recorded to 5.5 minutes per examination.

In the two centres where specialists perform the examination **and** imaging process, the working time for the three clinical situations varied between 12.2 and 13.9 minutes in Cluj and between 12.3 and 13.1 minutes in Vilnius. The total working time for the specialist in Cluj showed a range between 17.70 and 19.40 minutes and in Vilnius between 17.80 and 18.60 minutes. This resulted in a total labour cost per examination in Cluj with a mean of 0.41€ and in Vilnius a mean of 0.76€.

In the two other centres, Leuven and Malmö, where radiographers or dental assistants perform the examinations and imaging processing, the working time varied between 4.7 – 13.3 minutes in Leuven, and in Malmö the mean time was 10.5 minutes. This resulted in a labour cost per examination that varied between 2.68 and 7.58€ in Leuven and with a mean of 4.12€ in Malmö. The total labour cost per examination in Leuven showed a range of 4.68 – 9.58€ for all clinical situations and in Malmö it was an average of 9.17€.

3.1.2 Indirect costs

The mean total indirect costs per examination for the three clinical situations was 63.31€ in Cluj, 20.29€ in Leuven, 93.14€ in Malmö 32.22€ in Vilnius (Appendix 2). The indirect costs represent 70% of the total cost in Cluj, 52% of the total costs in Leuven and Malmö and 38% in Vilnius.

The fee for the radiographic examination was 58.06€ in Cluj, 5.61€ in Leuven, 102.02€ in Malmö and 5.95-82.13€ in Vilnius.

The time spent by the patients over 18 years old was valued per hour to 1.96€ in Cluj, 16.85€ in Leuven, 16.80 in Malmö and 2.84€ in Vilnius. For patients under 18 year the time per hour was valued to 0.40€ in Cluj, 6.72€ in Leuven, 7.84€ in Malmö and 0.72€ in Vilnius.

The resulting cost per examination regarding all three clinical situations for time spent by the patients is a range of 3.26 – 3.99€ in Cluj, 6.48 – 12.05€ in Leuven, 10.20 – 24.42€ in Malmö and 2.01 – 3.58€ in Vilnius. The valuation of cost for time spent by the accompanying persons is a range of 0.06 – 3.93€ in Cluj, 0 – 13.53€ in Leuven, 0.26 – 20.02€ in Malmö and 0 – 2.40 in Vilnius.

The average waiting time was 25 minutes in Cluj, 10 minutes in Leuven, 14 -19 minutes in Malmö and 10 minutes in Vilnius.

The travel-time was a range of 26.0 - 122 minutes in Cluj, 5.7 - 30.4 minutes in Leuven, and 0.3 - 58.9 minutes in Malmö.

The examination time was a range of 12.2 – 13.9 minutes in Cluj, 4.7 – 13.3 minutes in Leuven, an average of 10.5 minutes in Malmö and a range of 12.3 – 13.1 minutes in Vilnius.

For all three clinical situations, the patients' travel distance to the clinic one way was a range of 0.5 - 890 km in Cluj, 3 - 450 in Leuven, 0.1 - 600 km in Malmö and 0.5 - 450 km in Vilnius resulting in an average of 92km in Cluj, 25.5km in Leuven, 44km in Malmö and 30km in Vilnius.

In Cluj, between 30-50% of the patients came directly from another clinic, in Leuven it between 23-61% and in Vilnius between 34-66% of the patients. In Malmö none of the patients came directly from another clinic.

A majority of the patients who had an examination for retained canines were under 18 years and they often came with an accompanying person - 75% in Cluj, 100% in Leuven, 91% in Malmö and 50% in Vilnius. Regarding examination of the lower wisdom tooth, 33% in Cluj, 9% in Leuven and 4% in Malmö and Vilnius came with and accompanying person. In the case of the examination for implant planning all of the patients were over 18 years old and very few of them came with an accompanying person with 6% in Cluj, 0% in Leuven and Vilnius and 2% in Malmö.

4. Discussion and conclusions

The estimates of the costs of using CBCT as a diagnostic method for three different clinical situations (retained canines, implant treatment planning and lower wisdom teeth) vary considerably between the four country settings studied. The direct costs are highest in Malmö, Sweden followed by Vilnius, Lithuania, with the direct costs in Cluj, Romania and Leuven, Belgium being similar and approximately half that for Vilnius. Malmö also has the highest indirect costs (costs incurred by the patient and accompanying person) followed by Cluj and Vilnius with Leuven having the lowest indirect costs. We might expect differences in costs between countries associated with the different 'costs of living' and levels of wealth in the countries being compared which would lie outside the control of health care managers and policy makers.

However there is no clear association between these estimated costs and the economic well being of the country as measured by GDP per capita population. So although Belgium has a GDP per capita of almost $44,000 using World Bank data for 2009 [6], only marginally less than Sweden and around four times that of Lithuania and Romania, it has the lowest direct and indirect costs of CBCT. Hence variations in cost cannot be explained by the differences in economic well-being alone.

Careful consideration of the different elements of direct and indirect costs helps to identify a number of key factors that help to explain these cost variations. In particular:

The main determinants of the direct costs are the cost of the CBCT machine, the additional space for the machine and those who work with the machine, the volume of images performed and the method of delivering the service. The price of CBCT machine has fallen considerably over the last decade. Generally new technology tends to be most expensive when it is first introduced with prices falling, often substantially, as the technology is disseminated. As a result, those centres (Leuven and Cluj) purchasing the CBCT machine more recently have tended to pay around 75% of the price paid by the early adopters (Malmö and Vilnius). If, for example, Malmö had been able to purchase its machine in 2003 at the same price as Leuven paid in 2008 the direct costs per examination for Malmö would be reduced from 85,32€ to 73,10€. Paying this 'higher price' is not without some corresponding benefit, because the CBCT service has been available for use with patients in these centres for several years prior to access being made available to patients in the 'late adopting' centres.

The equipment cost per examination also depends on the amount of volumes being performed. For example, Cluj and Leuven paid similar prices for their CBCT machines but Leuven performs far more examinations thus producing a lower average cost per examination. This higher amount of volumes per year may represent greater levels of need in the population and/or use of the machine for a wider range of levels of severity.

[6] http://data.worldbank.org/ (last accessed 11 November 2010)

Increasing the number of tests by 25% in Malmö would reduce the direct cost per test by 12€. However there may be insufficient need within the catchment population served by the Malmö facility to warrant such increased levels of examination. In this case it might be worth considering opportunities to increase the catchment population by coordinating service delivery with facilities that serve neighbouring communities.

The space required for the machine varies between centres. This may be the result of facilities' existing structures. In Malmö the space devoted to the machine and its operation is over five times that reported as being used in Leuven. Reducing the space devoted to CBCT in Malmö by 33% would reduce the direct cost per test by around 6€.

Finally, the centres deliver the service using different staff mixes. In Cluj and Vilnius, radiologists both perform the examination and analyse and report on the image. In Leuven a radiographer is used to perform the test with the radiologist providing the analysis and report while in Sweden two dental assistants are used to perform the examination leaving the analysis and report to a radiologist. So, for example, if Malmö performed the examination using only one dental assistant, this would reduce the cost per examination in Malmö by approximately 2€. In the case of Cluj and Vilnius, substituting radiographer or dental assistant time for radiologist time in performing the test would also lead to reductions in cost per examination but only of around 1 – 1.5 €.

Indirect costs are those costs incurred by patients and the accompanying person, often family, arising from using the service. They arise from costs paid directly by patients (user fees, transport fares, parking fees) and those incurred indirectly (lost time from work or school). Patient charges represent the largest element of indirect costs in Cluj, in Malmö for implants and wisdom teeth and for implants in Vilnius. Patients charges in Leuven are small (5.61€) while in Malmö there is no patient charge for retained canines. These charges are usually outside the control of those responsible for delivering the service and reflect policy decisions at the broader health care system level. However patient charges are likely to influence the volume of examinations performed unless patients have some form of insurance through which such costs can be recovered.

The quantity of time patients and accompanying persons spend travelling to the facility is highest in Cluj and between 1.5 and 4 times the average patient time per examination in the other centres. This is because Cluj is one of only two CBCT machines in Romania and hence serves a much larger geographic population giving rise to much longer journeys to and from the facility on average than in the other centres.

A further factor influencing indirect costs is the organisation of the service. For example in Malmö, all patients are referred to the facility from other faculties. Hence each patient is required to make a separate trip to the CBCT facility. In the other centres between 20 and 70% of all patients arrive at the CBCT facility from other clinics in the same facility. Hence this involves no additional travel time for the patient and any accompanying person.

The following conclusions can be drawn:

- The estimates of the costs of using CBCT as a diagnostic method for the three different clinical situations (retained canines, implant treatment planning and lower wisdom teeth) vary considerably between the four country settings studied. The direct costs are highest in Malmö, Sweden followed by Vilnius, Lithuania, with the direct costs in Cluj, Romania and Leuven, Belgium being similar and approximately half that for Vilnius.

- Malmö has the highest indirect costs followed by Cluj and Vilnius with Leuven having the lowest indirect costs.

- There is no clear association between these estimated costs and the economic wellbeing of the country as measured by GDP per capita population.

- Generally new technology tends to be most expensive when it is first introduced with prices falling, often substantially, as the technology is disseminated. As a result, those centres (Leuven and Cluj) purchasing the CBCT machine more recently have paid around 75% of the price paid by the early adopters (Malmö and Vilnius).

- The equipment cost per examination also depends on the amount of volumes being performed. For example, Cluj and Leuven paid similar prices for their CBCT machines but Leuven performs far more examinations thus producing a lower average cost per examination.

- A factor influencing indirect costs is the organisation of the service. If each patient is required to make a separate trip to the CBCT facility the indirect costs are higher as compared to if the patients arrive at the CBCT facility from other clinics in the same facility (for example if the patient has an appointment at the orthodontist or oral surgeon in the same area and at the same day). Hence this involves no additional travel time for the patient and any accompanying person.

Appendix 1

Calculation of labour cost per hour for a specialist and a dental assistant with figures from Malmö, Sweden. Data is presented in EURO.

Calculation of labour cost per hour	
Specialist	
Annual gross labour cost for a specialist including on-costs (51% in Sweden 2008). Based on the valuation of wage and salary structures (general practice dentist) according to official statistics [16]. (Full time employment in Sweden is 1 980h)	87 074€
Annual labour cost for worked clinic hours (20% of annual gross labour cost)	18 892€
Worked clinic hours - hours worked in clinic according to schedule (350h) minus time for sick- and parental-leave (7h)	343h
Labour cost per hour = $\frac{\text{Labour cost for worked clinic hours (18 892€)}}{\text{Total annual worked clinic hours (343h)}}$	**55.08€**
Dental assistant	
Annual gross labour cost for a dental assistant including on-costs (51% in Sweden 2008). Based on the valuation of wage and salary structures (dental nurse) according to official statistics [16]. (Full time employment in Sweden is 1 980h)	36 756€
Annual labour cost for worked clinic hours (37% of annual gross employment cost)	13 551€
Worked clinic hours - hours worked in clinic according to schedule (1265h) minus time for sick- and parental-leave (114h)	1 151h
Labour cost per hour = $\frac{\text{Labour cost for worked clinic hours (13 551€)}}{\text{Total annual worked clinic hours (1 151h)}}$	**11.77€**

Appendix 2

Cost per examination

				Cluj	KUL	MAHOD	VU
Direct costs			Canines	26.97	21.85	85.32	52.60
			Implants	27.00	17.46	85.32	52.56
			Wisdom teeth	26.98	16.95	85.32	52.58
	MEAN:			26.98	18.75	85.32	52.58
	CBCT equipment			25.28	10.67	58.94	50.18
	Accommodation			1.29	1.60	17.21	1.64
	Labour	Specialists	Canines	0.40	2.00	5.05	0.78
			Implants	0.43	2.00	5.05	0.74
			Wisdom teeth	0.41	2.00	5.05	0.76
		Radiographers / dental assts	Canines	n/a	7.58	4.12	n/a
			Implants	n/a	3.19	4.12	n/a
			Wisdom teeth	n/a	2.68	4.12	n/a
Indirect costs			Canines	65.98	25.62	30.22	8.59
			Implants	61.38	17.66	127.02	82.13
			Wisdom teeth	62.57	17.59	122.19	5.95
	MEAN:			63.31	20.29	93.14	32.22
	Examination fee		Canines	58.06	5.61	n/a	4.18
			Implants	58.06	5.61	102.02	78.55
			Wisdom teeth	58.06	5.61	102.02	3.01
	Patient time valuation		Canines	3.99	6.48	10.20	2.01
			Implants	3.26	12.05	24.42	3.58
			Wisdom teeth	3.38	10.01	19.91	2.85
	Acc. pers. time valuat.		Canines	3.93	13.53	20.02	2.40
			Implants	0.06	0.00	0.58	0.00
			Wisdom teeth	1.13	1.97	0.26	0.09
	MEAN TOTAL			90.29	39.04	178.46	84.80


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