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DENTAL RADIOLOGY DOSIMETRIC DATA AS ROUTINELY COLLECTED IN AN ITALIAN HOSPITAL

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The work presented here was developed in the framework of the SENTINEL Project and is devoted to the analysis of dental radiology dosimetric data. The procedure of data processing allows the analysis of some important aspects related to the protection of the patient and the staff because of the position of the operators near the patient and their exposure to the radiation scattered by the patient. Dental radiology data was collected in an Italian hospital. Following the Italian quality assurance (QA) protocols and suggestions by the leaders of the SENTINEL Project, X-ray equipment performances have been analysed in terms of: kVp accuracy, exposure time accuracy and precision, tube output, dose reproducibility and linearity, beam collimation, artefacts and light tightness. Referring to these parameters the physical quality index (QI) was analysed. In a single numerical value between 0 and 1, QI summarises the results of quality tests for radiological devices. The actual impact of such a figure (as suggested by international QA protocols or as adopted by local QA routine) on the policy of machine maintenance and replacement is discussed.

INTRODUCTION

This study in the framework of the SENTINEL Project (FP6-012909) has been focused on the analysis of dosimetric data from dental and interventional procedures, gathered according to the questionnaires proposed by the leaders of Work Packages 2 (Efficacy and safety in digital radiology, dentistry and nuclear medicine) and 4 (Efficacy and safety in interventional radiology). All data were collected by the Medical Physics Department of Livorno Hospital (Italy), considered as a sample of the Italian quality assurance policy in this field.

Procedures such as dental and interventional radiology concern different clinical areas, but in terms of radiation protection they have some aspects in common. In both the practices in fact the operator is near the patient during the clinical examination and he is exposed to the radiation scattered by the patient.

At present only the collected data for dental radiology is considered, to demonstrate the application of the physical quality index (QI) for radiological devices.

MATERIALS AND METHODS

Data

According to the Italian quality control protocol, as implemented in the department, X-ray equipment performances were analysed in terms of: kVp accuracy, exposure time accuracy and precision, tube output, dose reproducibility and linearity, beam collimation, artefacts and light tightness. All data have been collected for each device with annual frequency after commissioning.

This work presents an analysis performed about peak voltage, time accuracy and tube output measurements for intra-oral and extra-oral devices. The number of considered devices is 19 (10 intra-oral devices and 9 extra-oral devices).

Data analysis aims to stress the most critical parameters (defined as those with higher occurrence frequency of out-of-tolerance events), eventually suggesting to modify their impact on the overall QI (as defined before[1,2]) and to introduce the measurement of alternative quantities.

With respect to the analysis of peak voltage and timer accuracy measurements, for each device the variation coefficient was recorded, defined as the ratio between the standard deviation and the mean value of these parameters, corresponding to a set of repeated measurements achieved every year after commissioning. Then, the variation coefficient values of the evaluated parameters were plotted as a function of time after commissioning in order to study their trend. In each plot the values corresponding to the quality control tolerance limit and the acceptance criteria threshold were entered, based on the Italian quality control protocol.

In particular, quality control tolerance limits define the envelop of characteristics within which the device is allowed to perform the work for which it has been planned and used, while acceptance criteria thresholds must ensure that the performance quality of the device remains constant during time and

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establish the reference values of these performances. In Table 1, the limits and threshold values are reported for the analysed parameters[3–5].

Physical quality index

The physical QI of radiological devices summarises the result of the constancy tests on a given machine in a real number whose value can vary between 0 (worst quality) and 1 (best quality).

The QI is defined by the equation:

$$QI = 1 - \sum_{j=1}^{M} \frac{f_i}{N_j + L_j} \left[2. \sum_{i=1}^{L_j} g_{i,j} + \sum_{i=L_j+1}^{N_j} g_{i,j} \right]$$

where M is the number of uses a device can be put to; f_j is the fraction of utilisation of the device in the jth mode, which can be determined based on the workload of the device; N_j is the total number of parameters subject to control for the jth operation mode; $L_j \leq N_j$ represents the number of parameters, relative to the jth operation mode, which are considered to be a priority in that they influence both image quality and the patient radiation protection; $g_{i,j}$ is a function named severity index, for the ith parameter of the jth mode, which is used to grade the influence of any difference between the parameter value and its tolerance on the QI[1].

This analysis allows to distinguish the different classes of devices in terms of QI and to identify the most critical parameters for each class, i.e. the parameters that most frequently yield negative results relative to the tolerances established in the quality control protocol. Finally, it is possible to redefine the QI in an 'adaptive' manner, adjusting it dynamically to the test results by weighting each parameter differently according to its criticality[1,2].

An example of the application of the QI is given for extra-oral equipment. For each device, the QI is computed in relation to each annual test (based on the parameters listed in the previous section). The distribution of the QI value for dental devices is presented and, for a single extra-oral device, the plot of the QI value as a function of years since commissioning. This particular device was chosen because this is a clear example of the use of the QI: the trend of the QI during time allows to identify a decrease of device performances and consequently to decide for a technical action, after which the best value for QI has been restored.

Table 1. Values of quality control tolerance limit and acceptance criteria threshold for variation coefficients of intra-oral and extra-oral devices.

	Intra-oral devices		Extra-oral devices	
	KVp accuracy (%)	Timer accuracy (%)	KVp accuracy (%)	Timer accuracy (%)
Tolerance limit	10	10	10	10
Acceptance criteria threshold	10	20	10	10

RESULTS AND DISCUSSION

In Figures 1 and 2 are presented the plots reporting the variation coefficient of peak voltage and time accuracy measurements as a function of the year since commissioning, for intra-oral and extra-oral devices. These plots show that variation coefficient values lie within both tolerance limit and acceptance criteria threshold for extra-oral devices. In contrast, for some of the intra-oral devices, the variation coefficient values of time accuracy measurements lie out of the tolerance limit but in any case within the acceptance criteria threshold.

Figure 3 shows the distribution of QI computed for extra-oral devices while in Table 2 is presented the contribution of different parameters to out-of-tolerance events (small value of QI). The distribution of QI shows a marked peak in correspondence with the high QI and a tail extending to relatively smaller

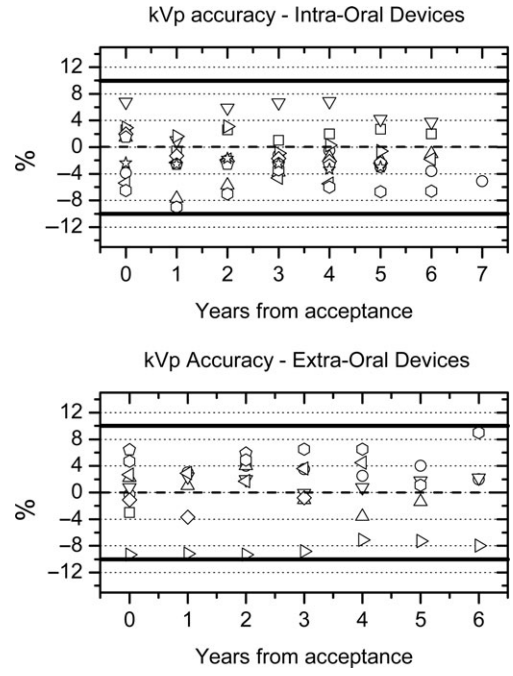

Figure 1. Evolution of variation coefficient for peak voltage measurements for intra-oral and extra-oral devices.

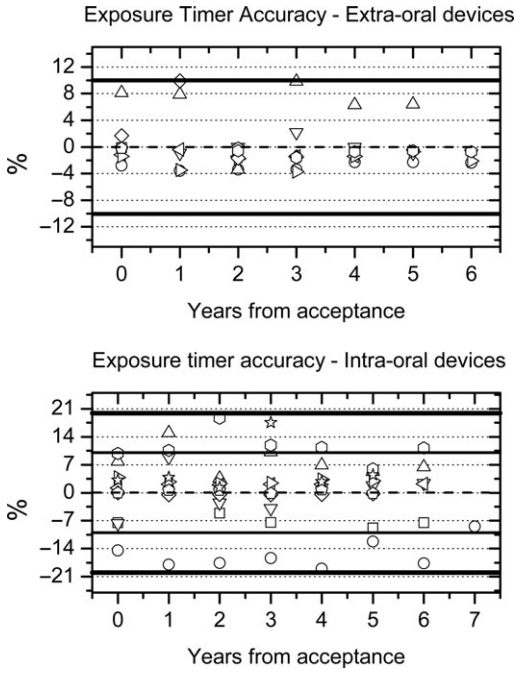

Figure 2. Evolution of variation coefficient for timer accuracy measurements for intra-oral and extra-oral devices.

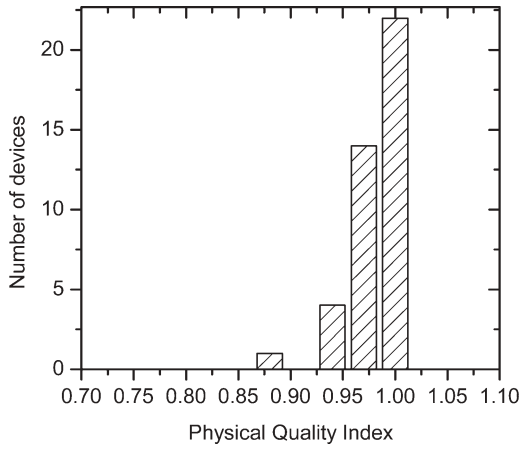

Figure 3. Distribution of the physical QI values computed for extra-oral devices every year after commissioning.

values. The asymmetric distribution towards high values suggests that the quality of most devices is acceptable, in fact 88% of the values are greater than the mean value (QImean = 0.977). Finally, in Figure 4 the trend of QI during time for an extra-oral device is presented. Relating to the previous

Table 2. Contribution of different parameters to out-of-tolerance events in intra-oral and extra-oral devices.

Intra-oral devices		Extra-oral devices	
Out-of-tolerance parameters (30% of total)	%	Out-of-tolerance parameters (7% of total)	%
Time accuracy	48	Collimation	50
Time precision	26	kVp accuracy	23
Dose reproducibility	14	Artefacts	15
Dose linearity	12	Light tightness	6
		Dose reproducibility	3
		Time accuracy	3

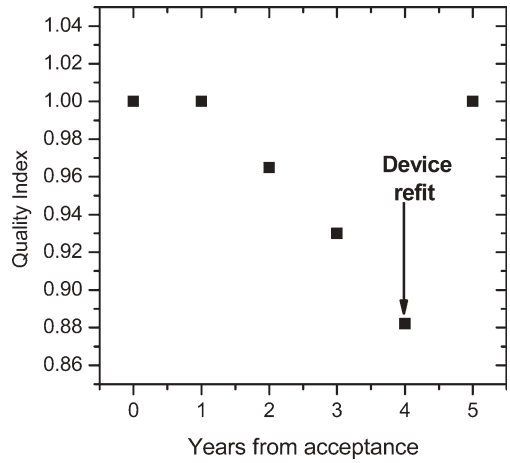

Figure 4. Time evolution for the physical QI for one of the extra-oral devices.

distribution of QI, the value 0.88 (<QImean) recorded at year 4 after commissioning the device represents an indication of loss of machine performances. In fact, after a technical action of maintenance, the best value for QI has been restored.

This example shows how the QI distribution can indicate a QI_t threshold for the QI, so that devices with $QI < QI_t$ will have to undergo extensive technical upgrading or must be replaced.

CONCLUSIONS

In the framework of the SENTINEL project attention has been focused on the analysis of dental and interventional radiological procedures and devices because of the radiation protection aspects they have in common such as the presence of the operators near the patient and their exposure to the radiation

scattered by the patient. In this paper some of the collected data for the dental procedures are presented, that is the data relating to those device parameters which have exhibited the higher influence in the computation of the physical QI.

This index was used to give a synthetic quantitative evaluation of the quality of the radiological devices. It was shown how monitoring the QI throughout the whole operating life of each device allows to identify the loss of performances and to plan corrective actions when the index goes below a certain threshold.

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