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ADVANTAGES OF LED LIGHTING SYSTEM IN COMPARISON WITH TRADITIONAL FLUORESCENT LAMPS FOR SIMPLE EXAMINATION ROOMS IN HEALTHCARE FACILITIES

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ABSTRACT

This paper presents a detailed comparison between a new type of antibacterial LED panel and fluorescent lamps connected to electronic ballast in a simple examination room, which requires 300 lx in a healthcare facility. Within the study, power consumption (W), luminous flux (lm) and luminous efficacy of both light sources were measured. Luminous flux values were then compared to the amount of power they consumed. Electrical power consumption of these luminaires was also analyzed. To enable an objective comparison between these two types of luminaires ReluxDesktop_2017.1.10.0 simulation program was used. To verify the results obtained by the ReluxDesktop, photometric measurement results of the products were also obtained. The results obtained by the study have shown that the LED panel to be used in the healthcare facility may decrease the maintenance and lighting costs by saving energy while maintaining the illumination levels required by the healthcare facility lighting standards.

Keywords: healthcare facility, lighting, energy efficiency, LED

1. INTRODUCTION

In terms of energy consumption, healthcare facilities can be considered as one of the energy intensive buildings because of the lighting requirements and of being 24/7 living structures. Therefore, they consume a very high amount of electricity, which equals to 11 % of the commercial electricity. When compared to the share of lighting in total energy consumption (16 %), the share of lighting in healthcare facilities reaches up to 44 % [1]. Thus, it is crucial to create a design, which will sustain the required lighting levels for patients and the hospital staff in different parts of the healthcare facilities while decreasing the energy consumption for the lighting requirements of them.

Energy saving is an ever changing and growing concept with the rise of LED lighting systems. It is not difficult to raise the savings up to 70 % in LED lighting systems with intelligent automation systems.

The improvement of LED technology changed a great deal of things in lighting field. Obviously, the most significant change is the energy efficiency that LED lamps can provide. The LED lamp consumes almost half of the energy of a conventional lamp while providing the same illuminance level [2]. This huge energy saving could also save a lot of natural resources and reduce carbon emission severely [3].

Performance and comfort limits in healthcare facilities defined by the relevant standards must be considered before applying a new lighting system. This will definitely enhance patient's comfort as well as staff's performance. The lighting requirements of healthcare facilities, in particular, hospitals are not only effectual to the patients but to the medical and non-medical staff as well when their

Table 1. Light Requirements for Different Hospital Areas According to EN12464–1

Task or activity	E_{av}(lx)	UGRL	U_0	R_a
General lighting	100	19	0.4	80
Simple examinations	300	19	0.6	80
Examination and treatment	1.000	19	0.7	90
Bathrooms and Toilets for Patients	200	22	0.4	80

tasks are taken into consideration. It is important to reduce mistakes and increase their performance via effective usage of lighting [4]. Moreover, the effects of lighting on people can also be both physiological and psychological [5].

The lighting system must be specified according to many properties which are: the illuminance level, the illuminance uniformity, the luminance distribution, the daylight availability, the prevention of glare, the colour rendering and the correlated colour temperature (CCT)[6]. The lighting requirements for each area in hospital have been set by EN12464–1 standard [7].

Hygiene is another important factor in healthcare facilities and the luminaire used in them is no exception. Thus, IP 65 luminaries should be applied to curtail maintenance costs and keep the dust and bacteria away from the luminaires. Coating the luminaire with antibacterial paint prevents bacterial growth [8].

By integrating different automation systems into different lighting applications in various parts of the healthcare facilities, it will be possible to save on energy and money and reach the desired efficiency. This study focuses on the most appropriate lighting type which will be visually and financially viable. Lighting for hospitals and healthcare facilities must be shaped in accordance with the economical, hygienic considerations stated above.

2. PROPERTIES OF HEALTHCARE FACILITY LIGHTING

In order to fulfil medical tasks, optimal illumination levels must be achieved and maintained at all times. High levels of visual comfort and the absence of glare on the eyes of staff is fundamental to the hospital staff while fulfilling their tasks. Doctors need glare-free lighting systems to perform their task, which is important since their tasks are mostly vital [9]. As well as doctors, nurses also need different illuminance for different tasks and areas to perform. [4]

When taken into consideration, it is vital to use lighting sources with colour rendering close to natural light [10]. This paper deals with simple examination room lighting on the examination plane for nursing tasks and simple examinations in a hospital. DIN EN12464–1 and DIN5035–3 recommend illuminance of around 300 lx on the examination plane for nursing tasks and simple examinations. Uniformity is another aspect in lighting, the ratio of maximum to average illuminance should be minimum 1:2. The lighting requirements of the rooms in hospitals can be found in Table 1.

Table 1 illustrates the most important requirements that have to be met by lighting in terms of parameters such as the illuminance uniformity (U_0), the colour rendering index (R_a) of the lamps and the maximum values of discomfort glare (UGR_L), the minimum values of average maintained illuminance (E_{av}).

Hospital infections have affected millions of people so far and it could not be prevented yet. Therefore, hospitals need to be sterilized all the time. In order to maintain sterilization, luminaires should be painted with anti-bacterial dye [8].

There are psychological and mental effects of lights as well as physiological effects. Researches show that a good psychological health helps people to get better faster. Proper lighting level can encourage healing process [5].

3. CASE STUDY AND METHODS

The case study has been conducted in a simple examination room in a hospital in Istanbul, Turkey. In the design, the hospital is considered to deliver high-quality care, sustainable 24 hours a day, seven days a week. The dimensions of the simple examination room are 12 m, height is 3 m and breadth is 6 m. The reflection coefficients are: 0.5 for the walls,

Fig. 1. Room graphic in 3D

0.2 for the floor and 0.7 for the ceiling. The required illumination measurement was taken on a work plane that has 0.75 m height. The required illuminance level for the simple examination room is 300 lx which has been set by relevant standards mentioned before.

The glare index and the colour rendering index will meet the standards to provide the necessary visual comfort for both patients and medical as well as non-medical staff. The lighting scheme is designed with an assumed maintenance factor 0.9.

The lighting simulation results for the study have been obtained by using ReluxDesktop simulation program, which supports the following standards: EN12464–1 (2013), EN1838 (2014), ASR A3.4 (2011), DIN5034 (1999); and photometric measurement results were taken by using NFMS Goniophotometer LabSphere Sphere System in line with the TS EN13032–1:2004+A1:2012 standards [11].

The examination room has been designed with reference to the given dimensions. Length, width, height, walls and ground material, and reflection factors have been defined. The furniture has been placed: there are 5 beds in the examination room. 2 types of luminaires have been selected from catalogue of ALKAN LIGHTING and placed to provide the illuminance has been defined in standards. ALKAN products: ALKAN, 53.AKSA.418.CPM (53AKSA418CPM.LDT) 4xT26 18W/840 and ALKAN – 7150511 LED Panel [12] were placed and simulated by ReluxDesktop, and then tested by NFMS Goniophotometer LabSphere Sphere System respectively (Scenario 1 and Scenario 2). Simulation and test results have been gathered, and they have been compared in terms of energy efficiency and cost effectiveness.

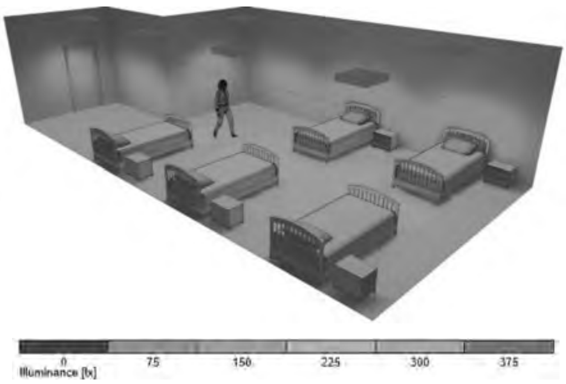


Fig. 2. 3D colour rendering

Table 2. Illuminance Data

Measured Surface	Work Plane Horizontal
E_{av}	330 lx
E_{min}	249 lx
E_{min}/E_{av} (U_o)	1:1.32 (0.76)
E_{max}	372 lx
E_{min}/E_{max} (U_d)	1:1.49 (0.67)
UGR (4H 8H)	<=21.5
Height	0.75 m

3.1. SCENARIO 1

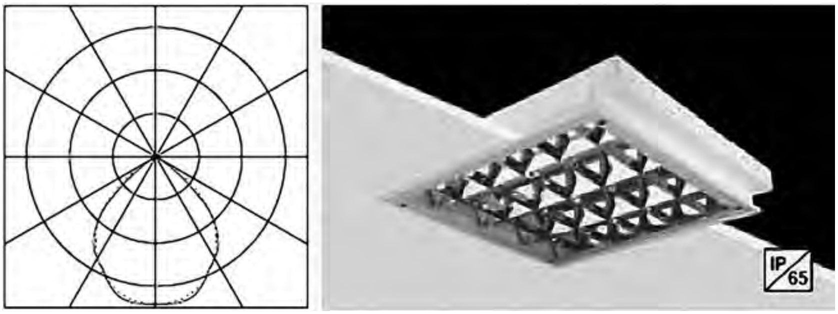
The fluorescent lamps type 53.AKSA.418.CPE produced by Alkan Lighting are used for the illumination of examination room of the hospital.

The lighting distribution values in lx are illustrated in Table 2. The luminous flux of the luminaire is 3507 lm and the total energy consumption of the luminaire is 74 W. The power consumption of electronic ballast is 2 W. The luminous flux of lamps of luminaire is 6400 lm. The energy efficiency can be calculated as: 3507 lm/6400 lm = 0.55

Totally 7 luminaires were used for the study. So, the total luminous flux is the sum of all the fluxes emitted by 7 luminaires and equals to 24549 lm. Also the total power used equals to 518 W.

According to result of ReluxDesktop program, the average illuminance measured at work plane E_{av} = 330 lx, the minimum illuminance measured at work plane E_{min} = 249 lx and the maximum illuminance measured at work plane E_{max} =372 lx.

Results of research are presented in Figs.1–6.



Efficiency of Luminaire	55 %
Efficacy of Luminaire	47 lm/W
Class	A60 100.0 % 0.0 %
CIE Flux Codes	74 99 100 100 55
UGR4H 8H	<10.0 / <10.0
Power:	74 W

Luminous Flux	3507 lm
Size	600 mm × 600 mm × 100 mm
Type	T26 18W/840
Colour	5911
Luminous Flux	3507 lm
Colour Rendering Index	85

Fig. 3. Photometric data

Fig. 1 shows the 3D graphic of the room, Fig. 2 presents 3D colour rendering data, photometric measurement results is in Fig. 3, Fig. 4 presents Value Chart (meter) data, floor plan is shown in Fig. 5, different surfaces reflection is presented in Fig. 6.

3.2. SCENARIO 2

Alkan product ALKAN – 7150511 LED Panel is used for the illumination of patient room of hospital. The lighting distribution values in lx are illustrated in Fig.7. The luminous flux of used luminaire is 4240 lm and total energy consumption of the luminaire is 40 W. The luminaire includes 18×9 LED lamps which make up 162 LED lamps. The driver

Table 3. Data About the lx Levels and Height

Measured Surface	Work Plane Horizontal
E_{av}	355 lx
E_{min}	262 lx
E_{min}/E_{av} (U_o)	1:1.35 (0.74)
E_{max}	414 lx
E_{min}/E_{maks} (U_d)	1: 1.58 (0.63)
UGR (3.4H 6.8H)	<=21.5
Height	0.75 m
Colour Rendering Index	85
CCT	4823

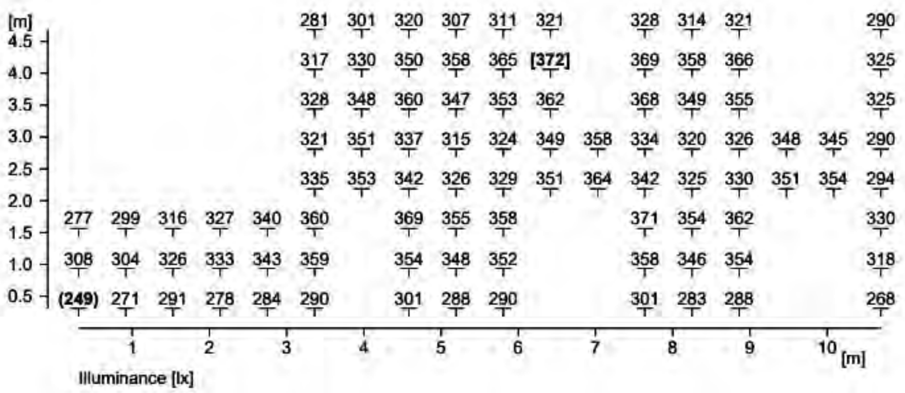


Fig. 4. Value Chart (meter)

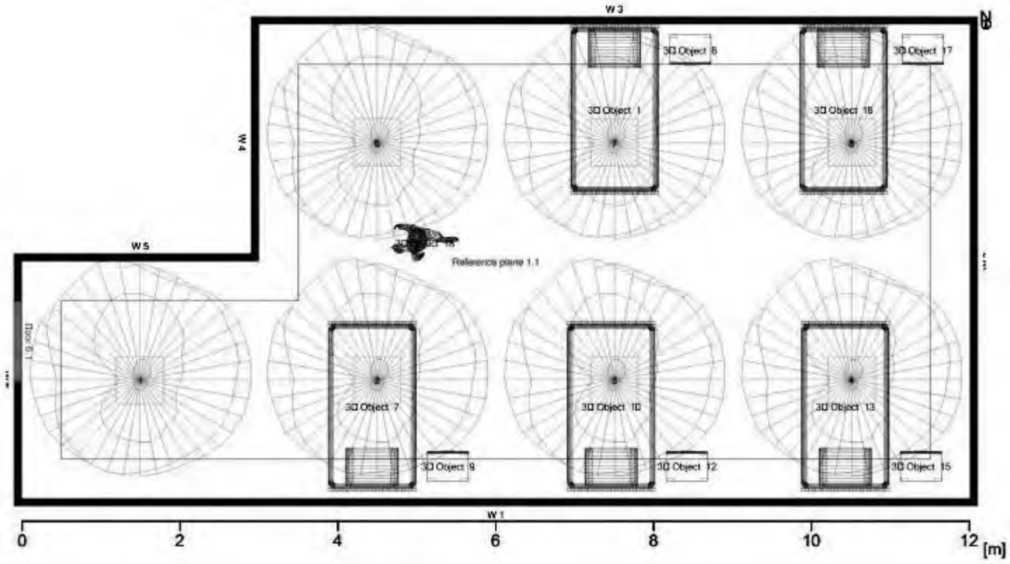


Fig. 5. Floor Plan

Wall	x, m	y, m	Length, m	Reflectance
1	12.00	0.00	12.00	50.0 %
2	12.00	6.00	6.00	50.0 %
3	3.00	6.00	9.00	50.0 %
4	3.00	3.00	3.00	50.0 %
5	0.00	3.00	3.00	50.0 %
6	0.00	0.00	3.00	50.0 %

	Reflectance
Floor	20.0 %
Ceiling	70.0 %
Room height	3.00 m
Height of reference plan	0.75 m

Fig. 6. Reflection of light from different surface

Table 4. Simulation Results Summary

Type	Φ (Lamps)	Φ (Luminaire)	Luminous	Φ Total
	[lm]	[lm]	Efficacy (lm/W)	(7Luminaire) [lm]
FL	6400	3507	47	24549
LED	6222	4240	106	29680

Table 5. Results of Photometric Measurements

Luminaire	E_{av}	E_{min}	E_{max}	U°
FL	330 lx	249 lx	372 lx	0.76
LED	355 lx	262 lx	414 lx	0.74

of the luminaire is 700mA. The power consumption of the driver is 2W and the power consumption of the LED lamps is 38W. The luminous flux of lamps of luminaire is 6222 lm.

The energy efficiency can be calculated as 4240 lm/6222 lm=0.68. Totally 7 luminaires were used for the study. The total luminous flux is the sum of all the fluxes emitted by 7 luminaires and it is equal to 29680 lm. Also the total used power equals to 280 W.

According to the results obtained from Relux-Desktop program, the average illuminance measured at work plane E_{av} = 355 lx, the minimum illuminance measured at work plane E_{min} = 262 lx and the maximum illuminance measured at work plane E_{max} = 414 lx.

Table 6. Luminous Efficasy for FL and LED Luminaires

Type	Power consumed P (W)	Total Power consumed P (W)	Luminaire Efficiency (%)	Total Φ (7 Luminaire) [lm]	Luminous Efficacy (lm/W)
FL	74	518	55	24549	47
LED	40	280	68	29680	106

Table 7. Economic Analysis Cost Comparasion:

	Fluorescent Luminaire	LED Luminaire
Operating Cost		
Luminaire Wattage (W)	74W	40W
Number of Luminaires	7	7
Daily Operating Hours (hrs)	24	24
Kilo-watt-hours per day (kWh)	12,43	6,72
Working Days Per Month	30	30
Total kWh per Month (kWh)	372,9	201,6
Total kWh in 10 years (kWh)	44748	24192
Installation Cost		
Cost of Installation per single luminaire ($)	24	65
Total Installation Cost of System ($)	72	455
Maintenance Cost		
Lamp Lifetime (h)	15.000	50.000
Quantity of the Luminaire in 10 years	6	2
Luminaire cost at the end of 10 years ($)	144	130

Fig.7. Room graphic in 3D

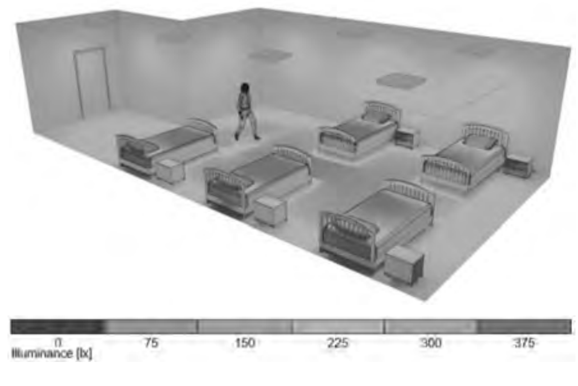
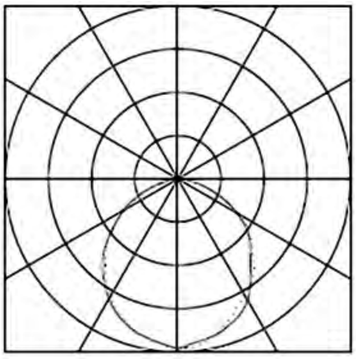


Fig. 8. 3D Rendering

Figs. 7–11 show the results obtained in SCENARIO 2 experiments.

4. RESULTS AND CONCLUSIONS

This study aims to analyze the energy efficiency of two types of luminaires in a healthcare facility by using simulations and making comparisons. The simulations were carried out by using an antibacterial LED panel, which was produced by Alkan Lighting Co. as a part of TUBITAK project number 7150511 and a fluorescent lamp connected to electronic ballast. Their power consumption (W), luminous efficacy and luminous flux (lm) were measu-



Luminaire information	
Efficiency of Luminaire	68 %
CIE Flux Codes	51 83 97 100 100
Size	600 mm x 600mm x 70 mm
UGR4H 8H	21.5 / 20.2

Efficacy of Luminaire	106 lm/W
Class	A40 100.0 % 0.0 %
Power	40 W
Luminous Flux	4240 lm

Fig. 9. Photometric data

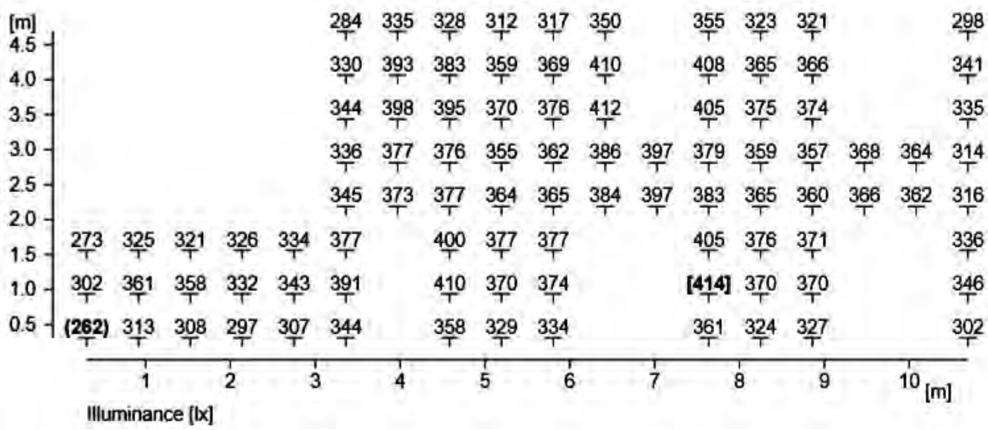


Fig. 10. Value Chart (meter)

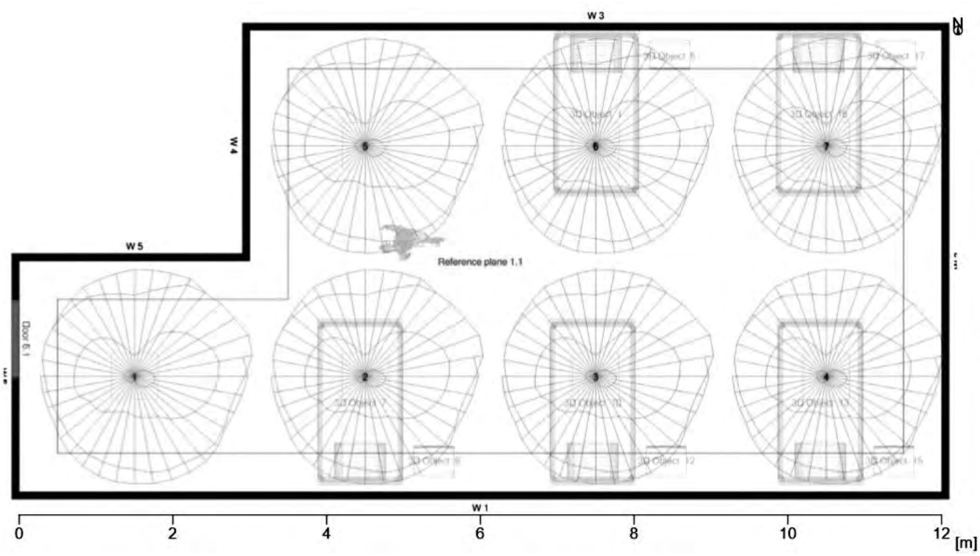


Fig. 11. Floor plan

Wall	x, m	y, m	Length, m	Reflectance, %
1	12.00	0.00	12.00	50.0
2	12.00	6.00	6.00	50.0
3	3.00	6.00	9.00	50.0
4	3.00	3.00	3.00	50.0
5	0.00	3.00	3.00	50.0
6	0.00	0.00	3.00	50.0

	Reflectance
Floor	20.0 %
Ceiling	70.0 %
Room height	3.00 m
Height of reference plan	0.75 m

Fig. 12. Reflection of light from different surfaces

red. The luminous flux values were then analyzed and compared with the power consumption of these luminaires.

Table 4 shows the results of the simulations of two different lighting systems in summary. The aim of the simulations is to illustrate efficiency of fluorescent lamp and LED. It can be concluded from the Table 2 that fluorescent lamp luminaire (47lm/W) has lower lm/W value when compared with LED luminaire (106 lm/W).

In scenario 1, FLs are utilized and the design consists of 7 luminaires, which give 372 lx levels at maximum. However, in scenario 2, LED luminaires are used in exchange for the fluorescent lamps and consists of 7 luminaires as well. The total amount of maximum level is 414 lx.

In scenario 1, the total luminous flux of the fluorescent luminaire lamps equals to 6400 lm and the luminous flux of the fluorescent luminaire equals to 3507 lm. When the luminous fluxes of the fluorescent luminaires are taken into consideration, it can be concluded that the efficiency of the fluorescent luminaire is 0.55. In scenario 2, the total luminous flux of the LED luminaire lamps equals to 6222 lm and the luminous flux of the LED luminaire equals to 4240 lm. Therefore, the luminous fluxes of the LED luminaires show that the efficiency of the LED luminaire is 0.68. In conclusion, once the luminaire efficiency is conceived, fluorescent lamp luminaires are 13 % less efficient than LED lamp luminaires.

While planning the study, in order to avoid extra expenses and labour, we anticipated to change 7 fluorescent luminaries with the same number of LED luminaires. While doing that, we kept the size of the LED luminaires the same as the fluorescent luminaires so as not to increase cost as a change in size would mean more civil and electrical work to be done, which will mean a rise in the expenses of the healthcare facilities. Thus, the number and the size of the luminaires had to be kept the same during the study.

When all the data collected in this study were examined, they show some striking differences between the commonly used fluorescent luminaires and LED luminaires. First of all, both types of luminaires provide the necessary illumination level (300lx) of a simple examination room. However, LED luminaire is efficient in providing the necessary illumination levels and it is almost two times more effective in this field. Secondly, total power consumption of fluorescent luminaires is nearly twice as much as the power consumption of LED luminaires (518 W/ 280 W). These figures suggest that while using fluorescent luminaires in healthcare facilities, we get almost the same illumination level despite consuming approximately twice much electrical energy compared to LED luminaires used in the study.

The economic performance of the LED luminaires in this study is significantly improved compared to the fluorescent luminaires with electronic ballast due to decreased costs and increased savings.

It can be concluded form Table 8 that lighting parameters UGRL, U_0, and Ra of the LED luminaire has better values then the fluorescent luminaire with electronic ballast.

Lighting up the health care facilities is a substantial duty for the continuity of the services of the facilities as well as for the well-being of the patients there. In order to achieve the required and desired

Table 8. The Values of Qualitative Characteristics

Type	UGR_L	U_0	R_a	CCT
FL	21	0,76	78	6041K
LED	13	0,74	85	5000K

illumination levels in these facilities, anti-bacterial LED luminaires is definitely a better option when compared to its older counterpart, fluorescent lamps in terms of being cost effective, supplying the required illumination level and being anti-bacterial, which will get rid of the unwanted side effects of the heat which causes the germs and microbes proliferate.

In conclusion, changing the fluorescent luminaires with the LED ones would mean not only saving up energy, which will also mean a decrease in energy expenditures, but also mean achieving the required illumination levels while keeping the sanitation high.

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