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Research Article

Analysis of Effects of Some Factors on Performance of a Dental Clinic

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Abstract

Quality and productivity management in healthcare has received considerable attention over the past four decades. Many research papers dealing with various aspects of healthcare performance have been published in the literature. However, medical organizations and hospitals are still lacking enough technical knowledge related to performance and quality improvement tools. This paper presents a procedure to study the effects of various factors on healthcare performance measures in a dental clinic. Particularly, we have analyzed a dental clinic system and investigated the effects of treatment types, dentist experience, and the patient age on treatment times using design of experiment and related analysis. The procedure presented here demonstrates a useful application of performance and quality improvement tools in healthcare organizations for healthcare managers.

Keywords: Healthcare Management, Dental Healthcare, Dental Treatment Times, Clinic Performance, Healthcare Efficiency, Design of Experiments.

Bir Diş Kliniğinin Performansını Etkileyen Faktörlerin Analizi

Öz

Sağlık hizmetlerinde kalite ve verimlilik yönetimi, son kırk yılda büyük ilgi gördü. Literatürde sağlık hizmeti performansının çeşitli yönlerini ele alan birçok araştırma makalesi yayınlanmıştır. Bununla birlikte, tıbbi kuruluşlar ve hastaneler, performans ve kalite iyileştirme araçlarıyla ilgili olarak hala yeterli teknik bilgiye sahip değildir. Bu makale, bir diş kliniğinde çeşitli faktörlerin sağlık hizmeti performans ölçümleri üzerindeki etkilerini incelemek için bir prosedür sunmaktadır. Özellikle bir diş kliniği sisteminde detaylı bir proses analizi yapılıp, deney tasarımı ve ilgili analizler kullanılarak, tedavi türleri, diş hekimi deneyimi ve hasta yaşının tedavi süreleri üzerindeki etkileri incelenmiştir. Burada sunulan prosedür, sağlık hizmeti yöneticileri için sağlık hizmeti kuruluşlarında performans ve kalite iyileştirme araçlarının yararlı bir uygulamasını göstermektedir.

Anahtar Kelimeler: Sağlık Yönetimi, Diş Sağlığı, Diş Tedavi Süreleri, Klinik Performans, Sağlık Hizmeti Verimliliği, Deney Tasarımı

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1. Introduction

Quality and productivity are the most important issues in the long-term success of industrial and service organizations. One of the most important issues in healthcare operations is performance management. In order to provide effective healthcare quality, performance management and related tools should be implemented in healthcare organization. Many research studies have been carried on healthcare management for effective use of resources. A brief review of related research publications is presented here.

Dey and Hariharan (2006) presented a case study on an integrated approach to improve healthcare quality and efficiency. Minkman, et al. (2007) have studied performance improvement of a healthcare system based on integrated quality management models. They have presented a complete literature review on the subject. Hodgetts (2008) indicated that effective people management increases quality of life and improves patient care and wellbeing in healthcare organizations. Therefore, medical human resources should be utilized effectively. Collett and Starke (2008) indicated that there has been increasing interest for the assessment of the performance of medical practitioners. Progress has already been implemented both in the UK and internationally. Poksinska (2010) discussed the current states of lean management in healthcare and indicated its importance in healthcare istitutions. Dewi et al. (2011) have researched patient satisfaction related to service quality of dental health care based on empathy and responsiveness. Savsar and Alajmi (2012) and Savsar (2017) analyzed surgical operations in an international hospital to determine significant factors that cause delays in these operations and affect productivity of the clinics. They describe key steps in designing and analyzing clinical systems for performance assessment and improvement. Rohatgi et al. (2018) also studied factors affecting delays in patient discharges in a general medicine service in an academic hospital.

System productivity and quality Improvements are interreated. Improving quality also improves productivity an efficiency. Several researchers have analyzed healthcare quality and thus improvement of efficiency. Dodwad (2013) did some research on quality management in healthcare to improve system quality and productivity. Islam (2014) indicated that guidelines for good clinical practice are the best examples of good and effective quality management and their evaluation. Goetz et al. (2014) discussed several important issues related to effectiveness of a quality management program in dental care practices. Bahadori et al. (2015) also have investigated several factors affecting dental service quality and proposed ways of improving service level. Karami (2016) tried to identify and utilize key performance indicators for decision making and system improvement in a radiology department of a hospital. Aaronson et al. (2018) have investigated patient experience rating and satisfaction in an emergency department.

Tyagi and Singh (2019) identified and prioritized some performance indicators, which are utilized in generating scenarios, as well as action plans for improving hospital performance management (HPM). They indicate that performance management bridges the gap between conceptual planning of organizational goals and the physical monitoring of the status of daily operations. Adhikari and Sapkota (2019) presented a procedure and results for measurement of management practices from the employer perspective of both public and private hospitals in Nepal and explored the relationship between management practices and output indicators of the hospitals by utilizing data collected from a primary survey. They concluded that better management practices are strongly associated with the indicators of performance of the hospitals. Kwateng et al. (2019) conducted a comparative study on perceptions of healthcare quality from the lenses of patients. They found out that there was a higher level of care and attention at private healthcare facilities than the public. It is recommended that there should be a strong collaboration between relevant partners to enhance service quality in the provision of healthcare.

Engineers and technical people in industry generally strive to apply available efficiency and optimization tools to improve system productivity and to reduce costs. It is important that healthcare systems and related activities are scrutinized, and available performance improvement tools are applied to various activities in order to provide better and timely services in crucial areas, where well beings of people are involved. One of the indicators of quality is efficiency and timeliness. Therefore, increasing efficiency of a system also results in better quality. Quality management tools have also been successfully applied in the analysis of the systems and determination of factors that affect important performance measures. It is essential to identify statistically significant components and factors in a system in order to control them for system improvement. This study explores applications of some efficiency and quality improvement tools in a dental healthcare system. We considered a school dental healthcare clinic, which serves the children from the age of six to fifteen years. We have tried to determine important factors that affect system performance measure, such as the time required to complete a treatment operation. In the next section, we briefly describe the clinic system, the activities involved, the performance measures considered, and the factors affecting these measures. It is followed by a detailed analysis using design of experiments and several related statistical analyses.

2. Methodology

2.1. System Analysis and Problem Description

The school dental clinic is responsible for the medical examination of new and current students in public and private schools in accordance with the health state requirement. It also conducts follow-ups of special cases and development of a follow-up health program on a case-by-case basis. The treatment is provided to residents of a special area in the city. Furthermore, the clinic offers many services and awareness programs for kindergarten students and elementary grade students at both private and public schools. For a student to receive service from the clinic, the student must have a record in the elementary or middle school database. The patients must provide their IDs to receive the service.

The mission of the School Dental Clinic is to promote health of the school community and to contribute on improving the educational attainment of students through the implementation of school health programs. Their vision is to have all children with a healthy and

active life. Working hours are from 7 am till 9 pm during the five weekdays. Emergency cases outside the official working days are directed to other specified clinics. Services provided at the center include:

- Periodic examination of the mouth and teeth
- Determination of a treatment plan
- Diagnosis and treatment of gum diseases
- Teeth cleaning
- Diagnosis and treatment of cavities and filling
- Root canal treatment
- Crown construction and fitting
- Tooth extraction for simple cases

Some special and complex cases, such as braces, fixed fixtures, mobile fittings, surgical ejaculation, dental implants, and periodontal surgery are transferred to other specialized dental clinics. School dental health system is defined as a set of concepts, principles, regulations, and services to enhance the health of school children and teachers and staff to promote the health of the entire community through schools, in active collaboration with community health authorities. School health programs and services are among the most cost-effective investments in health. School health is receiving increased attention from the governments. The school dental healthcare clinic is also working on the preparation of health awareness and education programs on the promotion of healthy teeth and regular hygiene awareness to prevent disease.

The processes and activities at the clinic were monitored and analyzed to determine the factors involved. One major function of healthcare quality management system is monitoring the processes. By doing so, the processes can be followed, and patients can be given optimal care. The clinic's system was analyzed in order to identify the critical factors that affect the final output and system performance. In this study, some features of the clinic quality are analyzed, and related aspects are studied. After some preliminary analysis, it was found that the length of time patients spend in the clinic was major concern and has been raised as an issue. Thus, the main objective was to determine the effects of various factors on the length of time a patient spends in the clinic to receive treatment.

The clinic currently operates with 30 doctors, 37 nurses, and 4 receptionists working at the clinic, along with 5 nurse supervisors that are responsible for making sure everything is going as planned. There are 18 treatment rooms in total, where 16 are general and 2 are specialized. The clinic has 1 X-ray room, a reception area, and 4 storage rooms. The school dental healthcare clinic received a total of 2825 follow up patients during the year 2018. Follow up patients are students that have previously received services from the clinic and are revisiting. Every year the clinic receives additional new patients. During 2018, 43 new patients were added to the total pool, where 47% of these new patients were male students and 53% were female students.

Furthermore, it is also necessary to understand the processes that a patient goes through. To identify the critical factors that affect the final output or system performance, several processes within the clinic were studied. This is important in improving the clinic's efficiency and productivity. After studying the process, we were able to get an overall view of how patients go through the system and are treated. Different ways to obtain an appointment, the types of treatments received, and the desired treatments were analyzed.

During the observation process, the clinic administration provided a list of treatments for which the patients come to the clinic. The specific treatments monitored were teeth cleaning, cavity removal, and crown placement. A total of 300 patient records were provided. Table 1 shows 131 of these records as a sample for illustration. The data is organized as a check sheet for easy interpretation. After detailed analysis of the process for 300 patient records, we determined that one of the critical factors affecting the time a patient spends in the system was the treatment type required by the patient. While monitoring the appointment process, we gathered data on the most common or the most demanded types of treatments. Healthcare practices should not rely on the single appointment and waiting room process. The management must recognize that effective patient flow is the answer to improving efficiency in the clinic.

The clinic's administration and reception staff oversee patient records. They record the patients name, medical history, age, and the treatment required. After analyzing some patient files, we realized the fact that delays and long treatment times were the result of various factors, including the type of treatment required, the patient age, and the dentist's experience, as well as the combination of these factors. The clinic tends to children from the ages of six to fifteen years old. The detailed analysis of the clinic system showed that the length of time a patient spends in the clinic for treatment was significantly affecting the productivity, quality, and effectiveness of the clinic. Therefore, it was necessary to identify important factors that affected the length of

treatment time. Based on the above studies, the observations, and the system analysis, we concluded that the important factors affecting treatment time were the type of treatment required for the patient, the years of doctor's experience, and the patient's age. These three factors were then further analyzed by analysis of variance, as well as using an experimental design procedure, to determine how significantly each factor affected the performance measure, i.e., the treatment time. Furthermore, the effects of individual factors and their combinations on treatment times were determined by using the available data and control charts. The data was collected over a 3-months period. Past data, charts, patient records, and schedules were collected from the clinic's administration and analyzed in this study.

2.2. Analysis of Data and Experimental Design

After determining the factors affecting treatment length, a factorial design of experiment was set up to analyze the statistical significance of the effects of these factors on system performance, which was the treatment time. The three factors A, B, and C considered had 3, 2, and 2 factor levels respectively as listed below.

A: Treatment Type (A1: Teeth Cleaning; A2: Cavity Treatment; A3: Crown Placement)
B: Years of Physician Experience (B1: <5 years; B2: ?5 years)
C: Patient Age (C1: <10 years; C2: ?10 years)

Data was collected on treatment times for all combinations of three factors at different levels. This resulted in 3x2x2=12 combinations. The factors and combinations of their levels are summarized in Table 2 below. Treatment times in minutes at different factor combinations are given in Table 3.

A general factorial design was used to run the experiment. To determine which of the factors affected the treatment time the most, we used Design Expert (He, 2003) to compare the factors. Design Expert is a statistical software that is specifically dedicated to performing design of experiments (DOE) using analysis of variance (ANOVA). Statistical significance of these factors is established with analysis of variance. Graphical tools help identify the impact of each factor on the desired outcomes and reveal abnormalities in the data. The response variable was the treatment time, and the factors were Treatment Type (A), Patients Age (B), and Physician's Experience (C) as given in Table 2 above. These three factors, A, B and C had 3, 2, and 2 levels respectively. The levels are labeled with (A1, A2, A3), (B1, B2), and (C1, C2) respectively as shown in Table 2. These levels resulted in 3x2x2=12 combinations. 20 observations were obtained for each combination, i.e., sample size was 20, which resulted in 20x12=240 data points, for which related response values are obtained and given in Table 3.

Table 1: Treatment type check sheet.

Patients	Treatments			Patients	Treatments			Patients	Treatments		
	Cleaning	Cavity	Crown		Cleaning	Cavity	Crown		Cleaning	Cavity	Crown
1	✔			44	✔			89		✔	
2			✔	45	✔			90	✔		
3		✔		46	✔			91		✔	
4		✔		47		✔		92		✔	
5	✔			48			✔	93	✔		
6	✔			49			✔	94		✔	
7	✔			50		✔		95			✔
8	✔			51	✔			96			✔
9		✔		52	✔			97	✔		
10			✔	53		✔		98			✔
11		✔		54		✔		99	✔		
12				55			✔	100		✔	
13	✔			56		✔		101		✔	
14			✔	57	✔			102	✔		
15			✔	58		✔		103		✔	
16	✔			59		✔		104			✔
17		✔		60	✔			105	✔		
18			✔	61		✔		106			✔
19	✔			62	✔			107		✔	
20		✔		63	✔			108	✔		
21			✔	64			✔	109	✔		
22	✔			65			✔	110		✔	
23			✔	66	✔			111	✔		
24			✔	67		✔		112			✔
25	✔			68	✔			113	✔		
26			✔	69		✔		114			✔
27		✔		70			✔	115	✔		
28	✔			71			✔	116		✔	
29		✔		72			✔	117	✔		
30			✔	73		✔		118		✔	
31	✔			74	✔			119		✔	
32			✔	75		✔		120	✔		
33			✔	76	✔			121		✔	
34	✔			77		✔		122	✔		
35	✔			78		✔		123		✔	
36		✔		79		✔		124	✔		
37	✔			80	✔			125			✔
38		✔		81		✔		126			✔
39		✔		82	✔			127	✔		
40	✔			83			✔	128		✔	
41			✔	84			✔	129		✔	
42			✔	85	✔			130		✔	
43	✔			86				131	✔		

Table 2: Factor Combinations

Combination	Treatment Type	Doctor Experience	Patient Age
A1B1C1	Cleaning	<5	<10
A1B1C2	Cleaning	<5	≥10
A1B2C1	Cleaning	≥5	<10
A1B2C2	Cleaning	≥5	≥10
A2B1C1	Cavity	<5	<10
A2B1C2	Cavity	<5	≥10
A2B2C1	Cavity	≥5	<10
A2B2C2	Cavity	≥5	≥10
A3B1C1	Crown	<5	<10
A3B1C2	Crown	<5	≥10
A3B2C1	Crown	≥5	<10
A3B2C2	Crown	≥5	≥10

Table 3: Response (Treatment Time) for all Factor Combinations

	Level 1 of A				Level 2 of A				Level 3 of A			
	B-1		B-2		B-1		B-2		B-1		B-2	
Sample	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2
1	35	30	30	30	29	20	23	16	45	45	45	30
2	40	35	25	35	27	26	20	15	50	45	40	35
3	40	35	35	25	28	25	25	20	50	45	40	35
4	45	40	30	30	28	28	24	21	55	40	50	40
5	50	35	30	30	25	27	21	18	60	40	45	40
6	35	30	35	35	29	26	22	19	45	40	50	35
7	45	30	30	25	30	25	24	17	45	35	45	35
8	35	45	40	35	32	24	27	19	60	35	45	35
9	50	45	35	30	27	23	23	17	55	40	50	30
10	45	35	40	40	29	25	22	20	50	40	50	30
11	35	40	45	35	26	23	20	15	50	40	50	30
12	45	30	30	25	30	26	20	17	50	45	45	40
13	45	45	30	30	32	28	25	16	55	45	45	35
14	40	35	35	35	31	24	22	18	45	35	50	35
15	50	40	40	35	24	25	24	19	45	35	50	30
16	35	40	45	30	27	23	23	16	50	45	50	35
17	40	35	30	40	26	24	21	16	55	40	40	35
18	30	30	35	25	32	26	25	20	50	50	40	30
19	40	35	30	25	27	28	24	21	50	45	50	35
20	35	45	30	30	25	24	21	18	55	40	45	30
Average	40.8	36.8	34	31.3	28.2	25	22.8	17.9	51	41.3	46.3	34

One of the assumptions required for the analysis is the normality requirement. Figure 1 shows the normal probability plot of the data, which shows that this assumption is met, and the analysis is valid. Analysis of variance was carried out for the factorial design in order to determine the factors and their combinations, which had significant effect on the response, the treatment time. Figure 2 shows the initial analysis of all factors as given by the DOE software. The results show that all factors, particularly factor A significantly affected the response. The results also show that the effect of interaction component AC was significant, while the others were not significant since they did not contribute much to the total variation in the response. The significant components were selected as labeled by M in Figure 2, and a detailed analysis was carried out based on these factors. Figure 3 shows the analysis of variance for the selected factors.

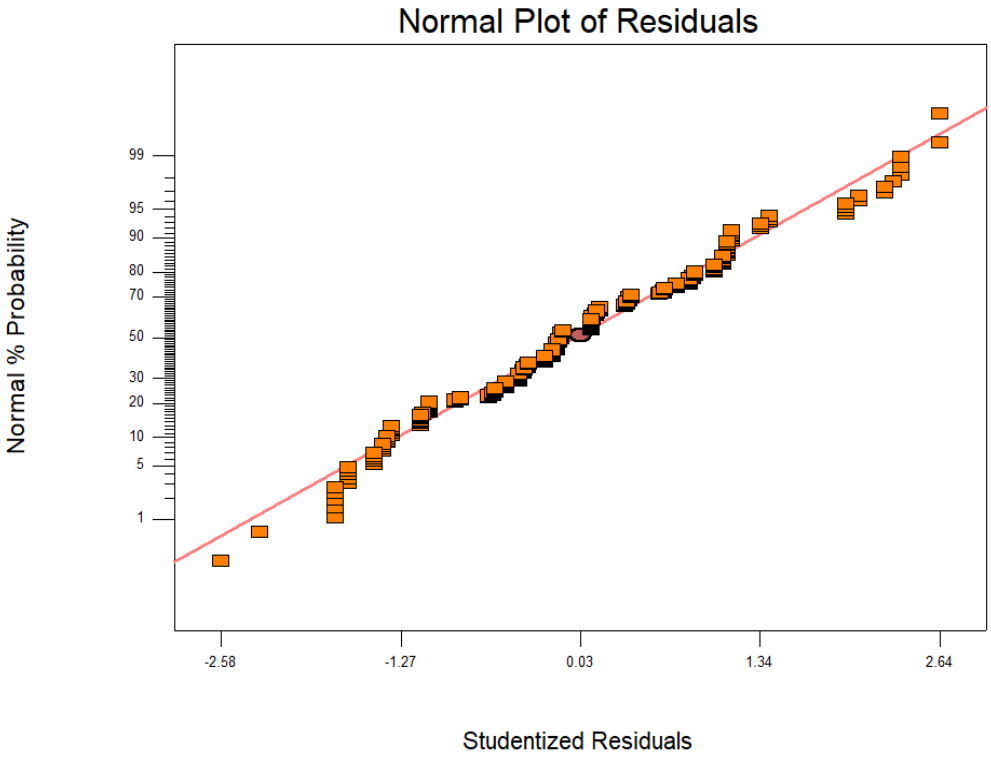

Figure 1. Normal probability plot of the data to check normality assumption

	Term	DF	Sum of Squares	Mean Square	F Value	Prob > F	% Contribution
	Intercept						
M	A	2	15748.91	7874.45	462.61	< 0.0001	63.22
M	B	1	2250.94	2250.94	132.24	< 0.0001	9.04
M	C	1	2263.20	2263.20	132.96	< 0.0001	9.09
e	AB	2	0.62	0.31	0.018	0.9818	2.509E-003
M	AC	2	712.66	356.33	20.93	< 0.0001	2.86
e	BC	1	14.50	14.50	0.85	0.3569	0.058
e	ABC	2	39.01	19.50	1.15	0.3198	0.16
e	Lack Of Fit	0	0.000				0.000
e	Pure Error	228	3880.95	17.02			15.58
	Residuals	228	3880.95	17.02			

Figure 2. Analysis of variance results for the three factors and their interactions

As it is seen in Figure 3, all three factors are significant at α=0.05 significance level based on F-value and Probability>F. However, majority of variation in treatment time was due to factor A, followed by factors B and C. Among the significant interaction components, the most contribution to the variation in treatment time was due to the interaction component AC, which represented treatment type and patient age.

Response: Treatment Time

ANOVA for Selected Factorial Model

Analysis of variance table [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	20975.71	6	3495.95	207.00	< 0.0001	significant
A	*15748.91*	*2*	*7874.45*	*466.25*	*< 0.0001*	
B	*2250.94*	*1*	*2250.94*	*133.28*	*< 0.0001*	
C	*2263.20*	*1*	*2263.20*	*134.01*	*< 0.0001*	
AC	*712.66*	*2*	*356.33*	*21.10*	*< 0.0001*	
Residual	3935.09	233	16.89			
Lack of Fit	*54.14*	*5*	*10.83*	*0.64*	*0.6724*	*not significant*
Pure Error	*3880.95*	*228*	*17.02*			
Cor Total	24910.80	239				

The Model F-value of 207.00 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A, B, C, AC are significant model terms.
Values greater than 0.1000 indicate the model terms are not significant.

Figure 3. Detailed analysis of variance results for significant factors and interactions

The interaction effects AB, BC, and ABC did not have much contribution to the variability in the response. The interaction effect AC, which was statistically significant, is shown in Figure 4, where y-axis represents the response (treatment time) and the levels of factor C, while x-axis represents the levels of factor A.

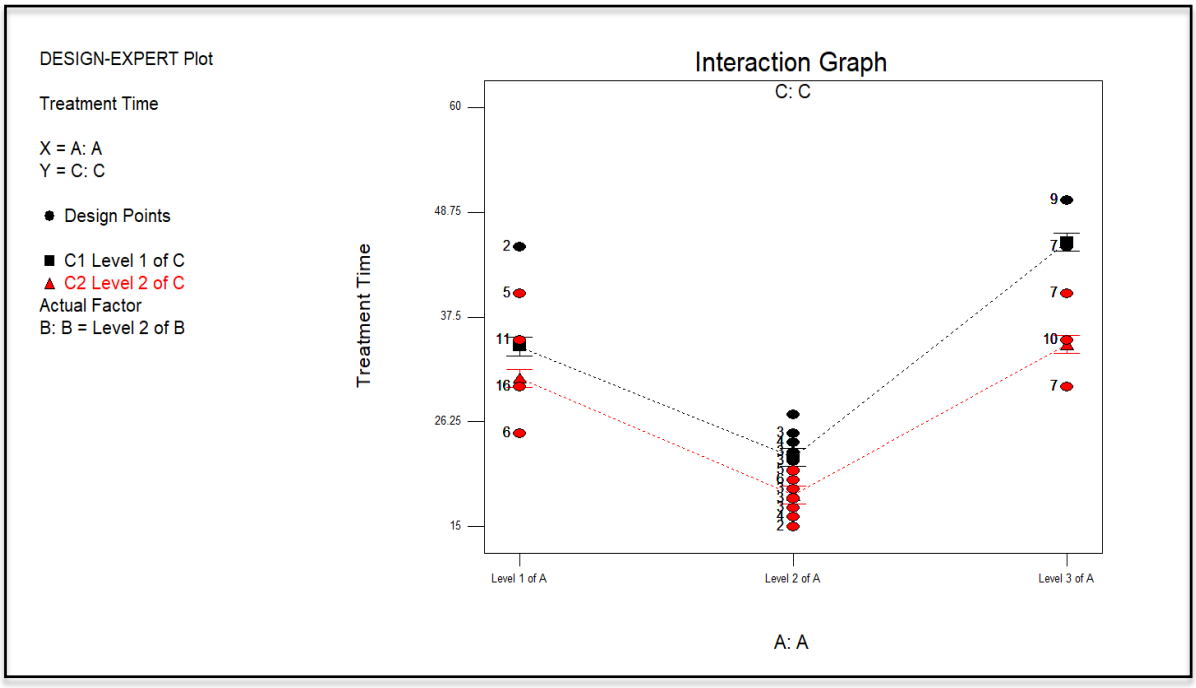

Figure 4. Interaction Graph between A and C

The figure illustrates how the interaction of the two factors affect the treatment time. The treatment time is highest at level 3 of A and level 1 of C as shown with the line at the rightmost corner of the picture. On the other hand, treatment time is least at level 2 of A and

level 2 of C, as shown on the middle of the picture. The implications of these results are that when the treatment type is crown fitting and the patient is less than 10 years old, the treatment time is longer regardless of the experience of the dentist. On the other hand, when the treatment type is teeth cavity and the patient is more than 10 years old, the treatment time is shorter regardless of the experience of the dentist. In order to see detailed analysis of the data, we present several tests related to the treatment time means in the following section.

2.3. Analysis and Comparisons of Treatment Time Means

combination In this section, we try to compare the treatment time means at different combinations of various factors in order to get more insight into the effects of these factors. The analysis is made by using the normal z-distribution and data analysis capability of excel. It is performed by selecting the functions Data- Data Analysis- zTest: Two sample Means in excel. Table 4 shows the comparisons of the dentist experience. The goal was to see how much treatment time would differ between a dentist with less than five years of experience and a dentist with five or more years of experience. As it is seen with the comparison of the means using a hypothesized difference of 6 minutes, there is in fact a difference of 6 minutes or more between the two types of dentists irrelevant of the type of treatment and the age of patient. Z value of 0.99663 is less than the critical value of 1.644854 at 95% confidence level, indicating that we cannot reject the hypothesis and that the difference is 6 or more minutes. The sample size was 120.

Table 4. Comparing dentists with respect to all treatment times.

z-Test: Two Sample for Means

	Experience<5 years	*Experience>=5 years*
Mean	37.158	31.033
Known Variance	93.123	95.648
Observations	120	120
Hypothesized Mean Difference	6.0	
Z	0.099663	
P(Z<=z) one-tail	0.460306	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.920612	
z Critical two-tail	1.959964	

Next, we tried to compare the treatment time taken by the two types of dentists for different types of treatments, i.e., cleaning, cavity, and crown. Table 5 shows the comparison results for the three treatment types. As it is seen from the results, the apparent difference was six minutes in all cases and the tested hypothesis showed that the difference was significant in all cases and we could not reject the hypothesis that the difference would be at least six or more minutes. The sample size was 40 in each case and the calculated z values, as well as the critical z values, are given in the table. From the results, it is evident that there is difference in treatment times between the more experienced dentists and the less experienced dentists. It is interesting that the difference was at least 6 minutes for all treatment types considered for all students less than 10 years of age and more than 10 years of age combined.

Table 5. Comparing dentists with respect to treatment times for all ages.

z-Test: Two Sample for Means	Cleaning		Cavity		Crown	
Doctors Experience →	*<5 years*	*>5 years*	*< 5 years*	*> 5 years*	*< 5 years*	*> 5 years*
Mean	38.75	32.625	26.6	20.35	46.125	40.125
Known Variance	35.641	28.196	7.475	9.822	44.21	51.91
Observations	40	40	40	40	40	40
Hypothesized Mean Difference	6		6		6	
z	**0.0989**		**0.3802**		**0.0000**	
P(Z<=z) one-tail	0.4606		0.3519		0.5000	
z Critical one-tail	**1.6449**		**1.6449**		**1.6449**	
P(Z<=z) two-tail	0.9212		0.7038		1.0000	
z Critical two-tail	1.9600		1.9600		1.9600	

The test was further extended to see if there were significant differences in treatment times between the dentists for patients less than 10 years of age and patients more than 10 years of age. Hypothesis testing was done for each class individually, but for all types of treatments combined. It was observed that the difference was slightly higher for patients more than 10 years of age. As it is seen in the

left side of Table 6, a hypothesized difference of at least 5.5 minutes for patients<10 years old was statistically significant between the two types of dentists since calculated z=0.0699 was less than the critical z=1.6449. On the other hand, a hypothesized difference of at least 6.5 minutes for patients >10 years old was again statistically significant since the calculated z=0.0801 was less than the critical z value of 1.6499.

Table 6. Comparing dentists with respect to patient age at all treatment times.

z-Test: Two Sample for Means **(Patients Less Than 10 Years Old)**		
Doctor Experience →	*<5 Years*	*>5 Years*
Mean	39.983	34.35
Known Variance	108.868	109.307
Observations	60	60
Hypothesized Mean Difference	5.5	
z	0.0699	
P(Z<=z) one-tail	0.4721	
z Critical one-tail	1.6449	
P(Z<=z) two-tail	0.9443	
z Critical two-tail	1.9600	

z-Test: Two Sample for Means **(Patients More Than 10 Years Old)**		
	<5 Years	*>5 Years*
Mean	34.333	27.717
Known Variance	64.4	62.88
Observations	60	60
Hypothesized Mean Difference	6.5	
z	0.0801	
P(Z<=z) one-tail	0.4681	
z Critical one-tail	1.6449	
P(Z<=z) two-tail	0.9362	
z Critical two-tail	1.9600	

If the hypothesis, that there is at least 5.5 or 6.5-minutes of difference between two types of dentists were rejected, the probability of committing an error would be 47.21% in the first case and 46.81% in the second case, as seen in Table 6. When the above test was repeated for individual types of treatments, similar results were observed. For example, for crown fitting type of treatment, there was difference of at least 4.5 minutes between the two types of dentists for patients less than 10 years old and a difference of at least 7 minutes for patients greater than 10 years old. These results are summarized in table 7. It should be noted that one-tail test was used since the test was to show that one of the means was greater than the second, i.e., $\mu 1 > \mu 2$.

Similar results, which are not shown here, were obtained for other types of treatments. All these analyses indicated that there was a difference in treatment times between the two types of dentists. It was also interesting that the difference was higher for older patients than for the younger patients. Effectively, the dentists with less experience performed better when dealing with younger patients. The above results showed that the less experienced dentists could be utilized more effectively with patients less than 10 years old as compared with the patients more than 10 years old. This is mainly because the difference in treatment times between the two types of patients is less pronounced for younger patients. This was true for all types of treatments individually. On the other hand, when the dentists were compared only with respect to treatment types ignoring the patient age, the difference between them was almost the same for all three types of treatments.

Table 7. Comparing dentists with respect to patient age for crown type of treatment

t-Test: Two-Sample Assuming Unequal Variances **(Patients Less Than 10 Years Old)**		
	<5 Years	*>5 Years*
Mean	51.00	46.25
Variance	22.632	15.461
Observations	20	20
Hypothesized Mean Difference	4.5	
df	37	
t Stat	0.1811	
P(T<=t) one-tail	0.4286	
t Critical one-tail	1.6871	
P(T<=t) two-tail	0.8572	
t Critical two-tail	2.0262	

t-Test: Two-Sample Assuming Unequal Variances **(Patients More Than 10 Years Old)**		
	<5 Years	*>5 Years*
Mean	41.25	34
Variance	18.092	12.105
Observations	20	20
Hypothesized Mean Difference	7	
df	37	
t Stat	0.2035	
P(T<=t) one-tail	0.4199	
t Critical one-tail	1.6871	
P(T<=t) two-tail	0.8399	
t Critical two-tail	2.0262	

3. Conclusions

Healthcare performance management is an important issue in healthcare organizations. When used appropriately, system productivity and performance can be significantly improved, in addition to increasing patient satisfaction and eliminating health care related errors and inefficiencies. Many researchers have studied quality and performance improvement in medical systems. Statistical tools used in industry need to be adapted to health care organizations.

In this study, we have investigated effects of several factors on system performance in a school dental clinic. Several factors, which affect the dental treatment time are considered and their effects are quantified with data collected. In order to show the significance of the effects of selected important factors on system performance measure, a design of experiment was set up and the collected data was analyzed to show the statistical significance of the effects of these factors. The results showed that the experience of dentists, the type of dental treatment and the age of students being treated had significant effects on treatment times. Furthermore, the interacting effects of treatment types and the patient age had significant effects on treatment time. The effects of dentist experience were studied at different levels of other factors. It was observed that there was statistically significant difference in treatment times between the experienced and less experienced dentists. It was also observed that this difference was more pronounced for students older than 10 years of age.

The procedures presented and the results obtained in this study can be utilized by the management to analyze any health care system performance and to determine significant factors which can be controlled to improve system efficiency. In this analysis, it appears that less experience dentists perform better on smaller age groups, which may possibly be attributed to less complications and simplicity in the treatment for these types of patients. The analysis and the performance assessment tools presented in this paper can help managers provide better service to society.

References

Aaronson, E. L., Mort, E., Sonis, J. D., More (2018) “Overall Emergency Department Rating: Identifying the Factors That Matter Most to Patient Experience”, Journal for Healthcare Quality. 40(6): 367-376.

Adhikari, S. R. and Sapkota, V. P. (2019) “Measuring hospitals performance: Applying the management approach in Nepal,” International Journal of Healthcare Management, 12 (4): 292-301.

Bahadori, M., Raadabadi, M., Ravangard, R. and Baldacchino, D. R. (2015) “Factors affecting dental service quality”, International Journal of Health Care Quality Assurance, 28(7): 678-689.

Collett, A. and Starke, I. (2008) “The assessment of doctors' performance: Tools and techniques,” Journal of Management & Marketing in Healthcare, 1(4): 400-411.

Dewi, F. D., Sudjana, G., and Oesman, Y. M. (2011) “Patient satisfaction analysis on service quality of dental health care based on empathy and responsiveness”, Dental Research Journal (Isfahan). 8(4): 172–177.

Dey, P.K., Hariharan, S. (2006) "Integrated approach to healthcare quality management: a case study", The TQM Magazine, Vol. 18 Issue: 6, pp.583-605.

Dodwad, S. S. (2013) “Quality management in healthcare”, Indian J. of Public Health. Vol. 57, No. 3, pp.138-143.

Goetz, K., et al. (2014) Effectiveness of a Quality Management Program in Dental Care Practices, BMC Oral Health, 14(41).

Hodgetts, S. (2008) “Effective people management in an ever-changing NHS environment,” Journal of Management & Marketing in Healthcare, 1(4): 324-326.

Islam, M. S. (2014) “Effective Quality Management in Dental Care Practice”, Rangpur Dental College Journal July 2014; Vol.2 No.

Karami. M. (2016) “Development of key performance indicators for academic radiology departments,” International Journal of Healthcare Management: 10(4): 275-280.

Kwateng, K. O., Lumor, R., and Acheampong, F. O. (2019) “Service quality in public and private hospitals: A comparative study on patient satisfaction,” International Journal of Healthcare Management, 12(4): 251-258.

He, L. "Design of Experiments Software, DOE software", The Chemical Information Network, July 17, 2003.

Minkman, M., Ahaus, K., & Huijsman, R. (2007) “Performance improvement based on integrated quality management models: what evidence do we have? A systematic literature review,” Int. J. of Quality in Health Care; 19(2): 90–104

Poksinska B (2010) The Current State of Lean /Intro in Healthcare. Quality Management Healthcare 19: 319-329. 15.

Rohatgi, N., Kane, M., Marcy, W. More (2018) “Factors Associated with Delayed Discharge on General Medicine Service at an Academic Medical Center”, Journal for Healthcare Quality. 40(6): 329-335.

Savsar, M. and M. M. Al-Ajmi (2012) “A quality control application in healthcare management using experimental design criteria,” International Journal of Health Care Quality Assurance, 25(1): 53-63

Savsar, M. (2017) “A Quality Control Application in Healthcare Management” Trauma Acute Care 2:30.

Tyagi, A. and Singh, P. (2019) “Hospital performance management: A multi-criteria decision-making approach,” International Journal of Healthcare Management Vol. 12, No. 4: 286-291.