AN EVALUATION OF EXPANDED FUNCTION AUXILIARIES IN GENERAL DENTISTRY

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Abstract

A simulation model of private dental practice has been developed to evaluate the effects of introducing expanded function auxiliary personnel. The model permits the experimental investigation of a variety of staffing patterns and facility configurations. Results of these experiments indicate that a solo practice can expand its patient volume 169% and increase net revenue by 233% by adding expanded function auxiliaries while simultaneously reducing patient waiting time and the time spent at chairside by the dentist. Field validations of the simulation results are described.

All segments of the American health care system are confronted today by the multiple challenges of increasing demand for services, rising costs, and a shortage of primary manpower. Due to social forces as well as population increase, the expected number of patient visits demanded per year in dentistry will increase by 100% from 1970 to 1980 [1]. However, the net increase of dentists in active practice is expected to be only 20.3% [2]. The cost (to the dentist) of providing care has risen from an average of $3.21 per patient visit in 1962 to $8.01 per patient visit in 1971 [3,4]. This rate of increasing cost is expected to continue into the future. Clearly, if adequate care is to be provided at a cost the average citizen can afford, new patterns of dental care delivery must be implemented on a wide scale basis.

One frequently proposed solution to these problems is the introduction of expanded function auxiliaries (EFA's) into private dental practice. The EFA is trained to perform many of the routine tasks now done by the dentist but not requiring his extended formal training. Empirical studies have shown the EFA's can perform selected tasks as quickly as the dentist with no reduction in quality [5,6,7,8]. The increases in dental practice productivity (number of procedures completed per unit time) resulting from employing EFA's are reported as ranging from 92% [9] (going from two operatories, one assistant to three operatories, two assistants and one EFA) to 150% [10] (going from one operatory, one assistant to three operatories, two assistants and one EFA).

These prior studies have established the EFA as a potential solution to the problem of increasing the capacity of the dental care delivery system. However, many basic questions remain to be answered before implementation can be expected. Specific task assignments need to be determined. Also it is not clear from previous research what staffing patterns are best in given practice settings. Further, no guidelines are avaliable to permit the private practitioner to evaluate the economic and patient flow effects of introducing EFA's into his practice. Analyses indicating the tradeoffs between potential increases in patient volume and gross revenues and increases in required physical plant and personnel costs are required.

To provide adequately the answers to these questions through empirical experimentation would be inordinately time consuming and expensive; there are too many feasible combinations of staffing patterns, task assignments, facility configurations and variations in management practices which need investigation. Further, it has been observed [8] that the variation between operators in pace is frequently greater than productivity differences resulting from small variations in staffing patterns and task assignments thus further complicating empirical experiments. Also, some promising staffing patterns and task assignments are prohibited from being incorporated into field trials by existing state Dental Practice Acts.

To overcome these problems, without eliminating feasible alternatives, a computer simulation of dental practice was developed. The simulation model represents dental practice in sufficient detail so that sub-tasks can be reassigned to personnel with various assumed levels of training. Decision rules on personnel assignment are also incorporated. The model does not, however, explicitly consider the micro-motion effects of variations in instrument location, operator posture, and so forth. These effects are subsumed in the activity time distributions.

Model Development

The simulation model consists of three basic parts: the patient generator, the logical network of the treatment process, and the cost model. The patient generator produces the input patient stream according to the specifications desired for a given run of the simulator, Present input specifications include: the mean arrival rate; random, scheduled, or scheduled arrivals with random deviations from the appointment time; reason for visit mix; reason for visit sequences (scheduled input patterns); and no-show and walk-in rates. The model currently uses 98 "reason for visit" codes; a typical visit mix is shown in Table 1.

Table 1 Typical reason for visit mix

Reason for visit	Percentage	Reason for visit	Percentage
Filling	29.0	Seat Bridge	0.6
Pumice Prophylaxis, Bite Wing Stannous Fluoride	17.5	Pick Up Dentures	0.6
		Bridge Prep	0.5
Check Up	10.7	Lost Filling	0.5
Diagnosis	5.2	Check Crown	0.4
Seat Crown	4.7	Check Wisdom Teeth	0.3
Extractions	4.2	Change Pack	0.2
Root Canal	3.2	Inlay Prep	0.2
Non-Coded	3.0	Gingivectomy	0.2
Toothache	2.7	Seat Inlay	0.2
Crown Prep	1.3	Gum Surgery	0.07
X-Rays	1.5	Scaling	0.07
Broken Tooth	1.5	Check Inlay	0.07
Curretage	1.5	Adjust Bridge	0.07
Functional Reline	1.3	Recem Root Canal	0.07
Pumice Prophylaxis	1.1	Gum Treatment	0.07
Impressions	1.0		
Seat Denture	1.0	New Patients	3.36
Suture Removal	0.8		
Adjust Dentures	0.8		
Check Dentures	0.8		
Shade and Mould	0.7		
Check Gums	0.6		

The logical network of the treatment process dictates the flow of the patients through the dental care facility. Although the treatment pattern for any dental procedure is fixed, the task assignments and branch points within a given procedure may be altered through input parameters. Approximately 300 input parameters determine the configuration of the model with respect to: the number of personnel, the staffing pattern, the task inventories of assistants, the number of operatories, the pace rating for procedure time distributions, the physical configuration of the facility, and certain decision rules for patient management.

A portion of the logical network is shown in Figure 1. The development of this network was a critical part of the model construction. It was based on several sources. The basic structure followed that developed at the Dental Manpower Development Center in Louisville, Kentucky [8]. Also, specifications of standard dental procedures as in Bell and Grainger [11], Guralnick [12], and Kilpatrick [13] were used. Further, the networks were compared to procedures used in private dental practices located in the Southeast. Finally, dental faculty from the University of Florida, College of Dentistry and dental officers of the U.S. Public Health Service reviewed the procedure networks and made many valuable contributions. Thus, the networks employed in the final model are representative of high quality dental care as practiced with current technology in the United States.

Event time probability distributions have been determined for 135 procedure codes. A partial list of procedure codes is shown in Table 2. A typical patient will be processed through approximately a dozen procedures during any one simulated visit. Again several sources of data were employed to develop the event time probability distributions. During the five year

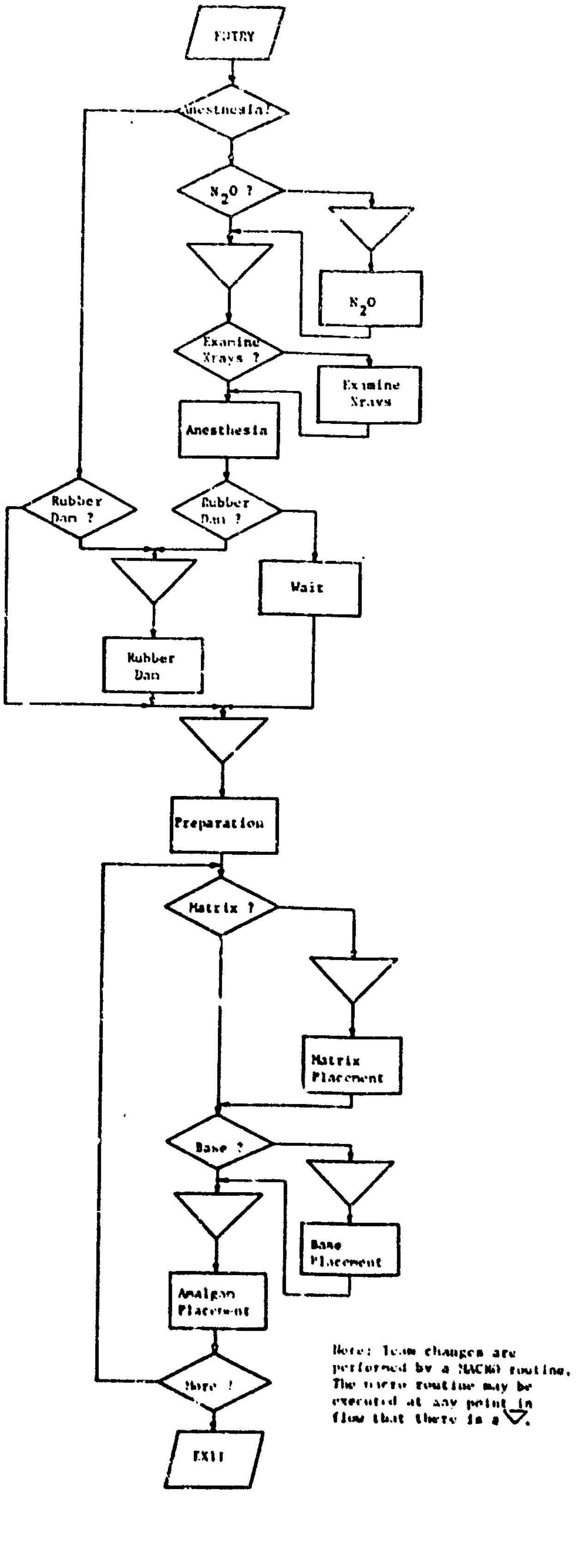

Figure 1 Portion of Treatment Network

Table 2

Dental Procedures and Code Numbers

	ADMISSION PROCEDURES		
001	Patient Preparation	205	Fluoride Application
002	Med. Hist. & Oral Exam.	206	Desensitization
003	Charting	207	Mouth Guard Delivery
004	Photography	208	Vincent's Treatment
005	Adult Radiographs	210	Gingivectomy
006	Pedodontic Radiographs	211	Pack Replacement
007	Edentulous Radiographs	213	Equilibration
008	Bitewing Radiographs		
009	Single Periapical Radiographs		OPERATIVE DENTISTRY
010	Special Radiographic Service	301	Simple Amalgam Preparation
020	Consultation Requests	302	Compound Amalgam Preparation
021	Oral Cytology	303	Complex Amalgam Preparation
022	Caries Testing	304	Cement Base
023	Bleeding Time	305	Matrix Placement
024	Vitality Testing	306	Amalgam Placement
025	Vitamin C Testing	311	Simple Amalgam Carved
026	Allergy Testing	312	Compound Amalgam Carved
027	Allergy Interpretation	313	Complex Amalgam Carved
028	Preparation of Smear	315	Temporary Filling
029	Smear Interpretation	321-9	One to Nine Amalgam Polished
050	Treatment Planning	330	Synthetic Preparation
060	Laboratory Orders	331	Base for Synthetic
		332	Synthetic Placement
	BASIC PROCEDURES	341-9	One to Nine Synth. Finished
160	Anesthesia	362	Compound Inlay Cavity Prep.
161	Rubber Dam Application	363	Complex Inlay Cavity Prep.
162	Vac-ejector Application	365	Direct Inlay Wax Pattern
163	Removal of Temporary Filling	370	Inlay Adaptation
170	Tray Selection	372	Inlay Cementation & Polishing
172	Alginate Impression		
175	Rubber Impression		CROWN AND BRIDGE
176	Stabilizing Rubber Impression	401	Full Crown Preparation
177	Solvite Impression	402	Three-quarter Preparation
		403	Jacket Preparation
	PREVENTIVE DENTISTRY	404	Dowel Preparation
201	Oral Health Instructions	411	Temporary Crown
202	Scaling	412	Temporary Shell
203	Pumice Prophylaxis	413	Try-in of Bridge
204	Recontouring		

Louisville study [8], event times were recorded for over 250,000 observed procedures. Event time probability distributions were derived from a 100% sample of these data [14]; typical distributions are shown in Figure 2. The Louisville data, although the largest event time data bank available, suffer from the fact that they were collected in a clinical facility of unique design employing Public Health Service dentists. Thus, the Louisville data were found to be statistically different from private practice procedure times. Two steps were taken to augment the Louisville data with data more representative of private practice. First, time-lapse video tape recordings were made of 3496 procedures in a private practice in Gainesville, Florida. Second, seven private practices in Cleveland, Tennessee had ten weeks of patient visits recorded on super-8 time-lapse film. An additional 50,000 procedures were analyzed from these data. The statistical analysis of these data indicated that for most procedures the time distributions were of the same form (i.e., gamma probability distributions of order 1 to 4) but showed significantly lower mean times than the Louisville data. The final distributions used in the model were then of two types: those determined directly from private practice data; and those, for which the private practice sample sizes were insufficient, which were based on the Louisville distributions with shifts of mean. Branch probabilities within the model, and proportions of subprocedures (e.g., the proportion of filling patients receiving anesthesia) were based on private practice statistics.

An important feature of the treatment model is the classification of auxiliary personnel by skill level. In addition to a dentist, and an optional receptionist, the model can employ any mix of EFA's of any of four assumed skill levels. The duties assigned to each skill level are shown in Table 3. The assignment was based upon rankings of task difficulty determined by expert judgment [15]. This structure allows considerable flexibility in developing staffing patterns for any given simulation run. The increased knowledge assumed for the higher skill levels is translated into higher salaries in the cost model. The assumption is made that all persons possessing the requisite skill will perform a given procedure with the same quality and time distribution. This assumption has been borne out in field studies [5,6,8].

The cost model permits the evaluation of the economic consequences of alternative staffing patterns, facility configurations, and management practices. More accurately, the 'cost' model should be termed a 'net revenue' model since this is the resultant figure of merit. The model can be summarized as:

$$
\begin{aligned}
\text{Net Revenue} &= \text{Revenue} - \text{variable costs} - \text{fixed costs} \\
&= [\alpha\gamma'(X+Y) + S'(X+Y) + e] \\
&\quad - [NS_D + (M_C + M_L)'(X+Y) + (O+U)'(X+Y) \\
&\quad + p_t v_t + i\gamma'(X+Y)] \\
&\quad - [NT(L) - F_{p,r}(N_{B1}, C_{B1})]
\end{aligned}
$$

The model components are listed in Table 4. Cost and fee data are entered as input parameters for the particular practice or region being studied. Economic data have been obtained from the private practices studied, from ADA sources and from various state and federal sources.

Table 3 Procedures assigned to assistants of various skill levels

RANKED LIST OF PROCEDURES ASSIGNED TO LEVEL 1 ASSISTANTS

RANK	DESCRIPTION
1	Patient Preparation
2	Release Patient from Chair
3	Informal Introduction
4	Vac-ejector application
5	Matrix Placement
6	Amalgam Placement
7	Synthetic Placement
8	Suture Removal
9	Polish Denture
10	Rubber Dam Application

RANKED LIST OF PROCEDURES ASSIGNED TO LEVEL 2 ASSISTANT

RANK	DESCRIPTION
1-10	All Level I Duties
11	Charting

RANK	DESCRIPTION
12	Fluoride Application
13	Denture Patient Instruction
14	Post Surgical Instructions
15	Polish Amalgams
16	Radiography
17	Placement of Base

RANKED LIST OF PROCEDURES ASSIGNED TO LEVEL 3 & 4 ASSISTANTS

RANK	DESCRIPTION
1-17	All Level 1 & 2 Duties
18	Alginate Impression
19	Pumice Prophylaxis
20	Oral Health Instruction
21	Simple Amalgam Carved
22	Synthetic Finished
23	Compd/Complex Amalgam Carved
1-23	All Level 1, 2, & 3 Duties
24	Scaling (Incl. Subgingival)
25	Medical History and Oral Exam

Table 4 COST MODEL COMPONENTS

α -- collection ratio on fees charged
X -- vector of annual procedure frequencies by dentist (column vector)
Y -- vector of annual procedure frequencies by assistants (column vector)
γ -- fees charged for procedures (column vector)
S -- vector of externally provided fees for service (column vector)
e -- external funding not related to service
N -- number of assistants (column vector)
S_D - salary paid per assistant (row vector)
M_C - material cost per procedure (column vector)
M_L - lab costs per procedure (column vector)
O -- miscellaneous overhead per procedure (column vector)
U -- utilities cost per procedure (column vector)
v_t - fair sale value of dental care facility
p_t - local tax rate
i -- insurance rate
T(L) training and hiring cost as a function of skill level
N_{B1}- number of operatories constructed and equipped
C_{B1}- construction and equipment cost per operatory
$F_{p,r}(\cdot)$ - annual mortgage payment based on r years at p percent interest

The present version of the model is coded in GPSS/360 version 2. The model reported on here consists of over 60 functions; there are 720 blocks and two schedule routines written in PL/1, several macros and a FORTRAN help block. The GPSS language was chosen for the initial coding and model development because it is flow related and economical of programming time. Consideration is being given to recoding the fully developed model into SIMSCRIPT prior to running the full range of experiments to reduce the computer time.

Model Validation

Several approaches to validation were used. The logical validity of the treatment network was determined through judgment of a panel of University of Florida, College of Dentistry faculty. This same panel reviewed the operation of the model in detail to verify that the patient flow patterns corresponded to realistic expections. It should be noted that since the model was simulating some staffing patterns not yet available in actual practice, direct comparison between model performance and actual performance is possible over a limited range only.

The most meaningful validation would be to compare the predicted performance of a given facility - staffing pattern configuration with the performance of an equivalent actual system. Two approaches of this type are presently being pursued. A private practice, not used in the original data base, will be observed using the same video time lapse techniques referred to earlier. These data will permit the development of frequency distributions on patient waiting time, dentist optional time, the idle time of assistants, total procedures completed, patient throughput time, costs and revenue. These distributions will then be compared to those generated by the model. A shortcoming of this approach is that it tests the model against only one facility - staffing pattern configuration. Further, since EFA's are not generally available in private practice, a crucial part of the model's predictive ability will not be tested.

To overcome this problem, arrangements have been made to participate in a National Institutes of Health study [16] in which EFA's will be introduced in seven private practices with varying physical configurations. Baseline data have been collected on these same practices. Hence, the ability of the model to predict the performance changes resulting from the introduction of the EFA's will provide a good test of model validity.

Measures of Effectiveness

The development of appropriate, comprehensive measures of health systems effectiveness and cost effectiveness is always a difficult problem. An attempt should be made to balance the needs and convenience of the patient population with the needs and motivations of the primary care providers. A typical procedure is to produce multi-dimensional system performance and effectiveness measures and attempt to strike a workable balance between conflicting measures; this approach was taken here.

Measures of system performance considered were: system capacity (maximum patient arrival volume), patient waiting time, personnel utilization, gross revenue, and net revenue. No attempt was made to assign a cost to patient waiting time. Rather, this statistic was produced to allow the decision maker (whether an individual dentist or national health planner) to determine a judgmental balance between patient waiting time and other performance statistics. The net revenue figure was viewed in two ways. First, since 91% of all active dentists are in private practice [2] the net revenue figure provides a motivator to serve increasing numbers of patients when it increases as assistants are added. Second, the net revenue was set at a certain arbitrary figure (say $40,000) and the fee schedule adjusted to achieve this figure exactly. This permitted an analysis of the potential savings to the consumer population when EFA's were added but allowed the dentist to maintain a reasonable income level. Both approaches are reported in the results section below.

Experimental Results

The results reported in this section represent a small subset of all possible experiments that could be performed with this highly flexible model. The experimental phase of this project will continue through 1974. The results given here are therefore illustrative only and conclusions drawn from them should be viewed as tentative.

A typical experiment analyzes the effects of varying two factors: the number of EFA's in a four operatory facility (1, 2, 3, or 4) and the skill levels (1, 2, 3, or 4) possessed by the auxiliaries. Each realization of the sixteen resulting combinations consisted of processing 500 patients through the treatment facility. The patient arrival rate (3 patients per hour) was such that the probability of no patients being available in the waiting room was negligible except at high levels of capacity. Overflow patients were assumed lost to the system.

Table 5 indicates the summary results. As can be seen in Figure 3 the greatest marginal gain in capacity is achieved in going from level 2 to level 3. Also note that with one assistant, the level of training has no effect on productivity. This is because the assistant is tied to the dentist as a chairside assistant and can not function autonomously.

The utilization of the dentist (Figure 4) increases and the utilization of the assistants (Figure 5) decreases as the system capacity increases. The dentist is working full time to keep up with his portions of the procedures and provide necessary supervision to the assistants as the staff size increases. However, since the level 4 auxiliary can do many of the tasks formerly done by the dentist, even at high patient volumes, the dentist has more optional time with level 4 assistants than with level 1.

Gross revenues (Figure 6) follow the same pattern as the number of patient visits, as expected. Because of the low marginal gains in capacity in going from a level 3 to a level 4 auxiliary and the attendant increase in salary, the net revenue (Figure 7) picture indicates that level 3 auxiliaries dominate the level 4's. On a purely economic basis, the best staffing pattern appears to be three level 3 auxiliaries. This also provides the dentist with 42% optional time and keeps patient waiting time to reasonable levels (an average of 6 minutes from the scheduled appointment time until the patient is seated in the operatory). The computer running time for a 2000 patient experiment (including compilation) was .94 minutes on an IBM 360/65.

Table 5 Simulation Summary Results

PRIVATE OFFICE: ONE DENTIST, FOUR Rx UNITS

LEVEL OF DENTAL ASSISTANTS	NO. D.A.	PATIENT VISITS PER YEAR	DENTIST UTILIZATION	D.A. UTILIZATION	REVENUE	NET REVENUE	FEE MULTIPLIER*
1	1	2.019	[illegible]	1.00	55.299	33.021	1.31
	2	2.419	1.00	.58	66.255	24.358	1.24
	3	2.437	1.00	.39	66.748	17.602	1.34
	4	2.437	1.00	.29	66.748	10.902	1.44
2	1	2.019	.71	1.00	55.299	22.371	1.32
	2	2.710	.96	.68	74.225	29.034	1.15
	3	2.834	1.00	.47	77.621	24.627	1.12
	4	2.795	1.00	.34	76.538	16.907	1.30
3	1	2.019	.20	1.00	55.299	21.621	1.33
	2	3.982	.42	.95	109.065	54.989	1.17
	3	5.360	.58	.88	146.807	76.830	.75
	4	5.414	.58	.68	148.286	68.009	.81
4	1	2.019	.18	1.00	55.299	20.321	1.36
	2	3.956	.38	.97	108.352	53.102	.80
	3	5.376	.53	.87	147.246	73.781	.77
	4	5.429	.50	.66	148.017	66.119	.82

*Fee schedule used in the revenue calculations must be multiplied by the factor indicated to achieve a $40,000 net revenue.

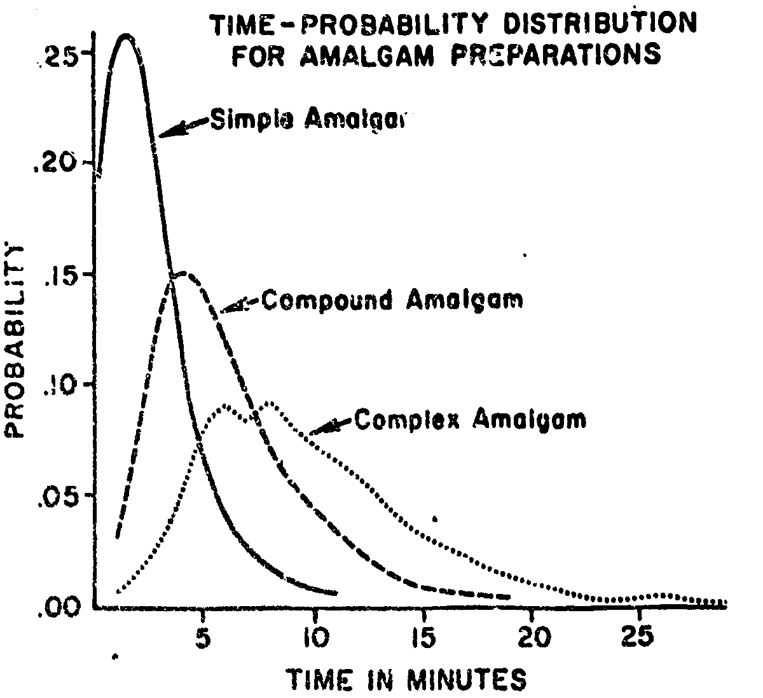

Figure 2 Probability density function for amalgam preparation.

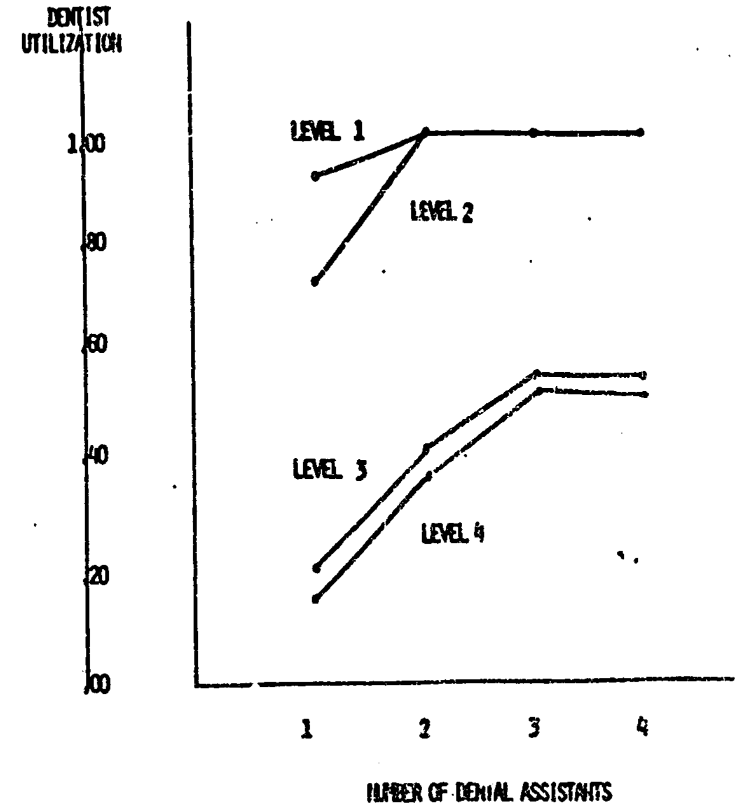

Figure 4 Dentist utilization as function of number of assistants.

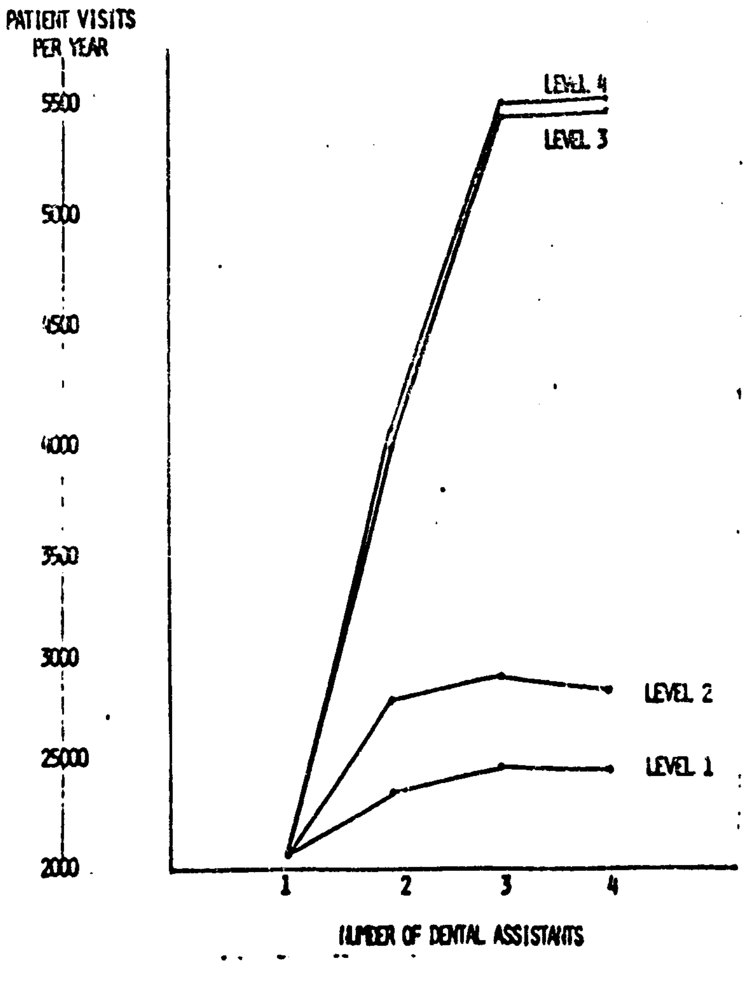

Figure 3 Productivity as a function of number of assistants.

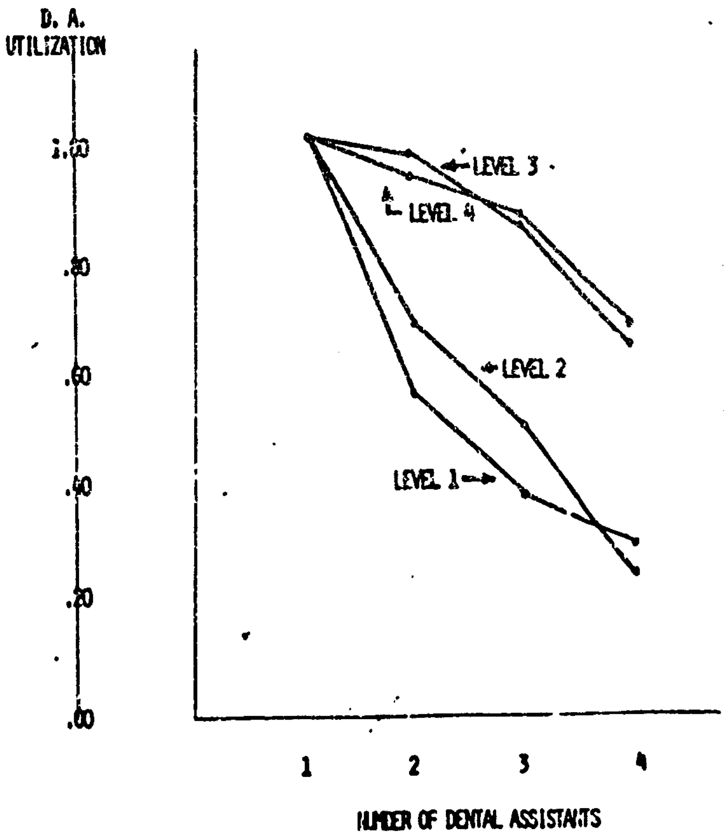

Figure 5 Dental assistant utilization as a function of number of assistants.

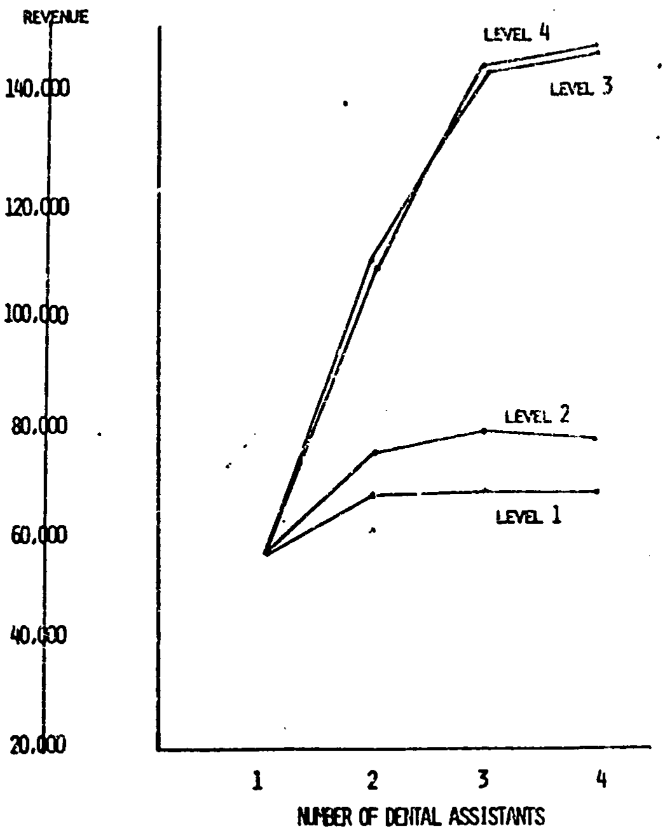

Figure 6 Revenue as a function of number of assistants.

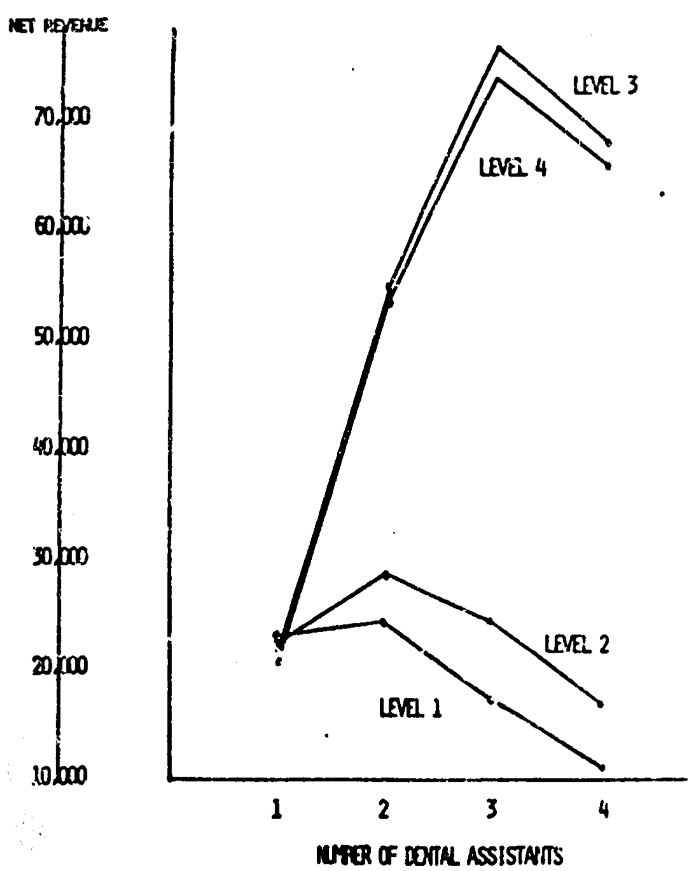

Figure 7 Net revenue as a function of number of assistants.

Conclusions and Implementation

Even in their preliminary state the foregoing results indicate that EFA's can significantly expand the capacity of a solo private practice. In addition, rather than overburdening the dentist, the proper utilization of EFA's will provide him with more optional time which can be used for continuing education, treatment planning, or other activities of direct benefit to the patient population. Further, there exits an apparent economic motivation for the dentist to use EFA's. Alternatively, the employment of EFA's offers one solution to check the rising costs of providing dental services.

With indications of such great benefits, the absence of EFA's in private practice needs some explanation. The most probable reason for their lack of use is that the American dental profession has not uet been convinced that the benefits suggested by limited field trials and simulation studies will actually accrue in practice. Further, the profession is not sure that some loss of quality of care will not occur with EFA's. Also, some dentists are uncertain as to their patients' reactions to being treated by EFA's.

The only convincing test of the model's conclusions appears to be a private practice field trial which is modeled after the 'optimum' configuration suggested by the model. As noted above, the Division of Dental Health (N.I.H.) study [16] is providing a partial demonstration of the EFA concept. Further trials of this type will however be necessary. To accomplish this goal, the developers of the simulation model are formulating plans for additional field trials which can be closely controlled and which will follow practice configuration guidelines as indicated by the simulation results.

Scope of Future Research

The collection and analysis of data, model development, validation, and preliminary experiments represent the first year's effort of a three year N.I.H. funded project. Further model development will include provision for endodontics, periodontics, and orthodontics. Provision for group practice arrangements will permit the analysis of various task distributions between specialists. Work is also progressing on incorporating improved patient scheduling procedures and team management concepts into the model to study their effects on the system performance measures. The development, test and validation steps occur on a continuing basis. The final conclusions of the research describe the exact field conditions over which a particular model configuration has been validated.

Work is also in progress to develop analytical models of the stochastic service system that is an abstraction of the dental care facility. Preliminary results [17] indicate that a steady-state GI/G/s queueing model will provide acceptable predictions of patient waiting time distributions. What is now required is the development of service distributions which are functionally dependent upon the facility configuration and staffing patterns.

The model is also being incorporated into the dental curriculum to provide a 'laboratory' for dental students to evaluate the effect of various practice management techniques on practice productivity. This on-line exposure will allow the student to observe the effects of various practice management modes over years of simulated practice in a few short sessions at a time-sharing terminal. The model will also be available to dentists already in practice for continuing education sessions.

Another ongoing study is the investigation of using the simulation model as a component of an overall planning model for national dental manpower needs. When properly validated, the model results can be extrapolated to national demand levels to predict manpower requirements under various staffing pattern mixes. The resultant manpower predictions would indicate not only the number and level of required personnel but the detailed skills inventories required for each personnel category.

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