A preliminary model of work during initial examination and treatment planning appointments

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RESEARCH

IN BRIEF

- Dental team members have multiple, often overlapping roles. They use a large and varied collection of equipment and technology to complete complex tasks.
- Technology often interrupts the workflow, causes rework and increases the number of steps in work processes.
- Current dental software could be greatly improved with regard to its support for all areas of the workflow process.

Objective This study's objective was to formally describe the work process for charting and treatment planning in general dental practice to inform the design of a new clinical computing environment. **Methods** Using a process called contextual inquiry, researchers observed 23 comprehensive examination and treatment planning sessions during 14 visits to 12 general US dental offices. For each visit, field notes were analysed and reformulated as formalised models. Subsequently, each model type was consolidated across all offices and visits. Interruptions to the workflow, called breakdowns, were identified. **Results** Clinical work during dental examination and treatment planning appointments is a highly collaborative activity involving dentists, hygienists and assistants. Personnel with multiple overlapping roles complete complex multi-step tasks supported by a large and varied collection of equipment, artifacts and technology. Most of the breakdowns were related to technology which interrupted the workflow, caused rework and increased the number of steps in work processes. **Conclusion** Current dental software could be significantly improved with regard to its support for communication and collaboration, workflow, information design and presentation, information content, and data entry.

INTRODUCTION

Currently more than 85% of the 166,000 dental practices in the USA and nearly 100% of dental practices in England and Wales use computers in their offices.[1,2] Moreover, England's National Health Service (NHS) plan includes an information technology strategy for NHS dentistry in the 21st century and £30 million has been allocated to integrate dentistry into the national information technology program.[3] This could suggest that technology has achieved a relatively good match with the task requirements and workflow in dentistry. However, a large majority of dentists both in Britain and the US use computers only for administrative purposes, not in the clinical environment.[4,5] This low rate of clinical use stands in stark contrast to the fact that the clinical utility and benefits of computers in clinical dental care have been articulated for many years.[6-8] In surveys of clinical computing in dentistry in Britain and the US,[4,5] participants listed many barriers to and disadvantages of computers in the clinical environment, such as lack of space, inefficient systems, insufficient operational reliability (eg system crashes), functional limitations of the software, the learning curve, cost, infection control issues and insufficient usability.

This survey data provides useful background information, but does not allow for a detailed understanding of workflow and information management issues and how technology impacts them. A detailed literature review located three observational studies,[9-11] only one of which used ethnographic methods to study dental practice prior to the implementation of an information system.[9] In that study, Button *et al*. observed the workflow of seven US military dental clinics. The researchers conducted on-site interviews, observed clinicians in their work environment, collected copies of chart entries and forms, and identified steps in clinical processes. The study found significant differences between dental and medical workflow, evidenced in part by a mismatch between the design of the software and the way the dental clinics operated. Button *et al*.'s work provided an incomplete picture of workflow, partially because they did not use a formal and systematic analysis methodology such as contextual inquiry (CI).

As evident from the literature, there is no comprehensive, empirical model for clinical work in the dental office. The objective of our study, therefore, was to develop a detailed understanding of workflow and information management during initial examination and treatment planning appointments in general dentistry. Specifically, we want to learn how dental clinicians work together, communicate, and interact with their environment, and how technology is integrated into the workflow.

This project is significant because it has developed a preliminary, comprehensive model of work during initial examination and treatment planning

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Table 1 Summary of contextual inquiry observations, storage media for patient charts and radiographs, operatories and practice management system in use

Office	Patients	Patient chart**		Radiographs		Operatories		Practice management system	
		Paper	Computer	Film	Digital	Number	With computer	Vendor	Use
1	2	X			X	5	3	Dentrix	Administrative
2	1		X	X	X	6	6	Dentrix	Clinical
3*	3	X		X	X	4	4	Dentrix	Administrative
4	1	X		X		1	0	Dentrix	Administrative
5*	5	X	X	X	X	4	4	Dentrix	Clinical
6	1	X		X		3	0	SoftDent	Administrative
7	2	X			X	2	1	EagleSoft	Administrative
8	2	X		X		3	0	SoftDent	Administrative
9	1	X	X		X	6	6	SoftDent	Clinical
10	1	X	X		X	6	6	EagleSoft	Clinical
11	3	X		X		5	0	Cobb	Administrative
12	1	X			X	5	5	SoftDent	Administrative
Totals	23	11	4	7	8	$\bar{X} = 4.2$	$\bar{X} = 2.9$		

*One observation was conducted in each office, with the exception of offices 3 and 5.
**'Patient chart' denotes all patient documentation except radiographs and billing/insurance processing.

appointments. The results of this study can inform the design of systems for not only the US but other countries as well. While the model was developed to inform the design of computer systems to support work,[12] it has several other potential applications such as education in office and practice management, and the analysis of practice operations.

METHODS

For this research project, we followed the contextual inquiry (CI) method as described by Beyer and Holtzblatt[12] and applied, among others, by Fridsma *et al.*[13] The research team included six members with experience in dentistry, dental informatics, human-computer interaction and the CI methodology.

We limited observations to initial examinations and treatment planning appointments. Based on our survey study,[5] we selected communication, collaboration, and information acquisition, storage, management and retrieval as our research foci. We chose general dentistry as the professional context, because the overwhelming majority of dentists in England and the US are general dentists[14,15] and including dental specialties would have injected a large amount of variability into the observed work processes and environments. Prior to the observations, the research team developed a general set of questions to guide the observers. Questions ranged from the general, such as 'Which patient findings are recorded?' to the specific, such as 'How many computers are in the office?'

By telephone, we recruited nine male and three female dentists and their support staff from Pittsburgh, Pennsylvania, USA, using a random sample obtained from the American Dental Association (ADA). Following the methods of CI and rapid contextual design,[16] the first author and a member of the research team performed all observations. During the observations, the researchers recorded salient findings and observations in writing and occasionally asked questions about what they were observing. After the patient visits, the observers debriefed the dentist/staff members and asked any remaining questions regarding the observation.

As soon as possible after the conclusion of the CI session, but never more than 72 hours afterwards, the two observers met for an interpretation session to review the raw observation notes and develop the five CI work models and recorder notes. Whenever there was a question as to how to handle a particular information item, the observers referred to the standard CI and rapid contextual design techniques.[16] After all CI sessions were completed, the research team produced consolidated summative models for each CI model type, and organised the information from the recorder notes into the affinity diagram, a hierarchy revealing common issues and themes.

The research protocol was classified as exempt under Title 45 CFR Subtitle A Part 46 and approved (IRB number 0501154) by the University of Pittsburgh Institutional Review Board.

RESULTS

We conducted 14 observations in 12 of the 38 offices who had received information about the study, a response rate of 32%. We observed a total of 23 patient visits. Table 1 presents a general overview of the dental offices, the number of patient visits observed, the use of computers/paper for information management and the operatory/computing infrastructure. Nine of the participating dentists were male and three female. The participants collectively graduated from four different dental schools. We completed approximately 20.5 hours of total observation time. The interpretation sessions, during which we developed the five models, took one to one and a half hours on average for each observation. We will now discuss the models that resulted from the observations; the models can be obtained by contacting the first author.

The consolidated flow model

The consolidated flow model (Fig. 1) provides an overview of individuals, roles, tasks, artifacts and interactions in the work process of initial dental examination and treatment planning appointments. Roles tended to overlap; the dentists' and dental hygienists' roles were primarily clinical, the front desk personnel's primarily administrative, and the dental assistants' a mix of the two.

All communication among work process participants was two-way, thus every person either communicated or exchanged an artifact with every other person. Thirty-eight of the communication pathways supported information management, while 24 were related to other types of tasks. In the process, 11 different types of artifacts, ranging from the tray sheet to the chart, were transferred among team members and the patient. Three artifacts, the patient chart, routing slip and medical history, were transferred most frequently (five times each), whereas the remaining eight were transferred only once. The tray sheet occupied a special position among artifacts inasmuch as it served as a temporary 'information store' when the clinician wanted to record patient information (either in the chart or the computer), but could not do so directly due to infection control or other constraints. Sometimes, information from the tray sheet was transcribed into the patient record; at other times, the tray sheet simply served as a transient information store. The tray sheet was always discarded.

The computer was used to store/manage clinical information other than images in four offices, and to store/manage radiographs in eight. Every team member interacted with the computer.

The consolidated sequence model

A consolidated sequence model consists of an overall trigger and intent related to the work process being modelled, in our case initial examination and treatment planning. The model consists of a list of activities, each of which has one or more intents, ie goals to be achieved. Achieving each goal involves completing one or more abstract steps. Breakdowns, ie interruptions to the workflow, are included in each action sequence where they occurred and are marked in red.

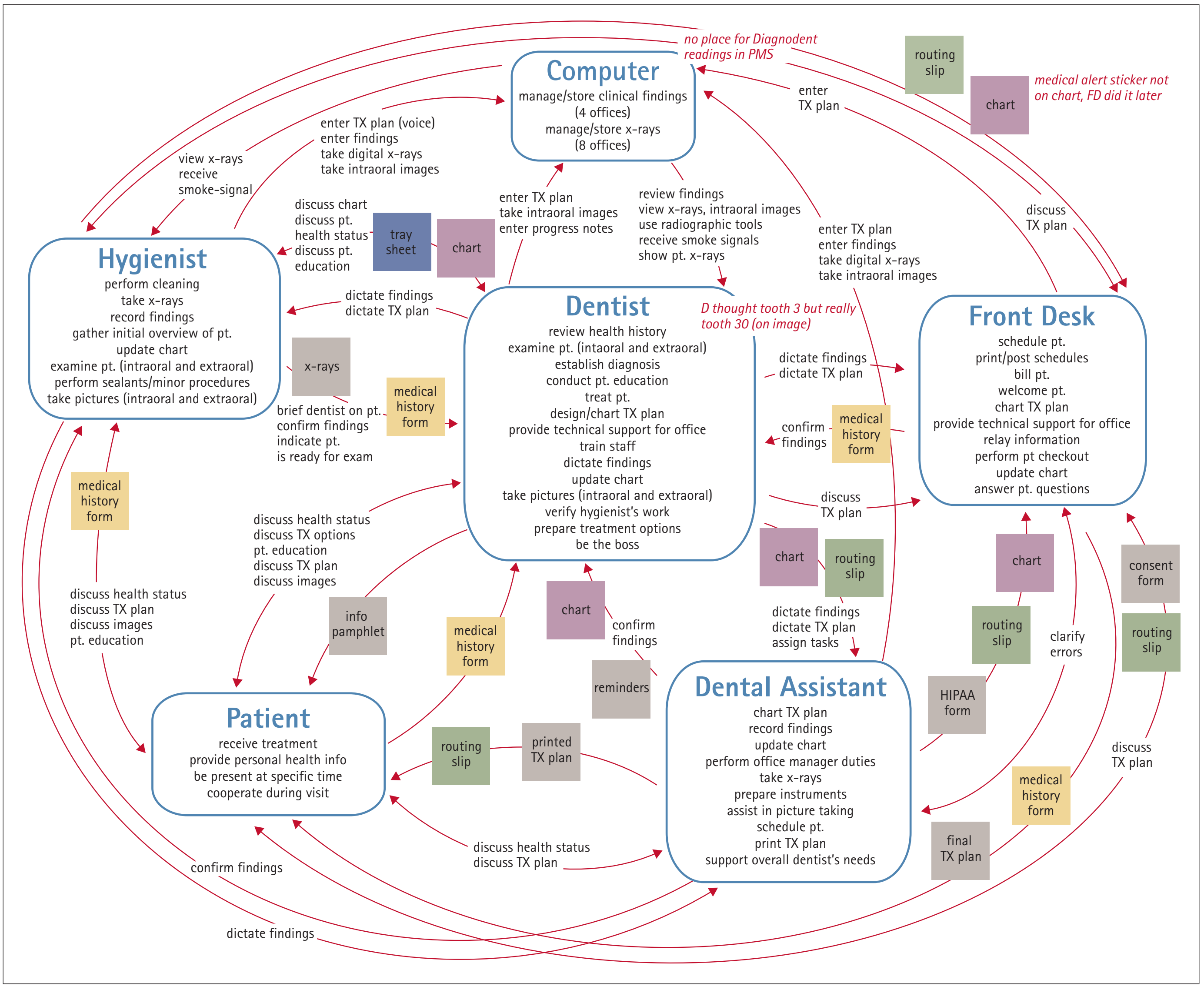

Fig. 1 Consolidated flow model. A representation of individuals, roles, tasks, artifacts and interactions in the work process
***The computer was present in eight of the 12 offices. Abbreviations: pt = patient; TX = treatment. Breakdowns are indicated in red**

Table 2 Consolidated sequence model for one sample task. Breakdowns are indicated in red

Activities	Intents	Abstract steps		
		Main strategy	Alternate strategy 1	Alternate strategy 2
Take X-rays	Clarify concerns or discover new problems Make sure pt is comfortable	(10 steps) • D orders X-rays • H talks with pt about discomfort of film • Loop: 1) put film in mouth; 2) adjust X-ray table; 3) expose film; 4) remove film for developing; 5) develop film • Take additional X-rays • Breakdown: X-ray equipment unreliable – had to take multiple times (represents two break-downs) • Check to make sure X-ray is of proper quality	(21 steps) • Get laptop for digital X-rays • Get digital sensor • Put infection control on sensor • Connect sensor to the computer • Start X-ray software application • Explain procedure to pt • Put sensor in pt mouth • Double-click computer to activate sensor • Move X-ray machine • Breakdown: pop-up on computer about staying connected interrupts office flow • Go outside operatory and expose film • Computer makes noise to indicate pic taken • Check computer to be sure pic took • Breakdown: H had to take X-ray twice because of bad first image • Breakdown: 2nd X-ray didn't take because of smoke signal • Breakdown: too many steps in digital X-ray process (represents four breakdowns) • H talks with pt about discomfort of sensor • Loop: 1) move sensor in mouth; 2) adjust X-ray table; 3) expose film; 4) check com-puter • Breakdown: H had to restart record mode on sensor for X-ray • Breakdown: X-rays are not labelled with tooth number automatically; way of enter-ing that information is too cumbersome • Place sensor back in holder	(3 steps) • H, A v D takes pt PAN *(the intermediary steps of taking a PAN were not observed)* • H, A v D develops PAN • Labels PAN with pt name in permanent ink

Overall intent: Provide dental care to patient.
Overall triggers: 1) Patient arrives for appointment; 2) Staff is aware patient is in the operatory.
Abbreviations: pt = patient; D = dentist; A = assistant; H = hygienist; pic = picture.

The overall intent of the consolidated sequence model was to provide dental care to the patient (see Table 2 for an excerpt of the sequence model). The major activities in the sequence model (number of steps in the main strategy in parentheses) were 'Obtaining initial clinical information' (10), 'Taking X-rays' (10), 'Reviewing clinical information (dentist)' (13), 'Conducting the soft tissue and extraoral exam' (4), 'Charting periodontal conditions' (9), 'Charting hard tissue conditions' (12), 'Taking intraoral pictures' (14), and 'Diagnosing conditions and planning treatment' (24). Of the eight tasks, three each had one alternative strategy and two alternative strategies, respectively. 'Taking X-rays' comprised 10 steps using conventional celluloid film (main strategy), but 21 using digital radiography equipment (alternate strategy).

The consolidated sequence model shows that hygienists and assistants perform most of the data collection steps while the dentist performs some. Data collection and review is a collaborative activity; for instance, in several offices hygienists conducted a preliminary extra- and intraoral exam, briefed the dentist on the major findings and then recorded additional findings made by the dentist. Throughout the model, the dentist dictated information to either the hygienist or assistant six times, while he/she recorded information directly only once.

The consolidated artifact model

The consolidated artifact model (see Fig. 2 for an excerpt of the model) is a collection of the most important artifacts (physical objects) used during the observations. Each artifact in the model is a composite representation of all versions of the artifacts collected during the CI sessions.

The major artifacts observed during the work process were the 'medical/dental history form', the 'hard tissue chart', the 'periodontal chart', the 'treatment plan form' and the 'routing slip', and their corresponding equivalents on the computer. Most of the forms, especially those for data gathering, contained a mix of different data types such as free text, numbers, check boxes and graphical annotations. Offices used a variety of conventions to encode information. We did not observe duplicated information among the forms with the exception of the routing slip. Most of the information on the routing slip was already recorded on other forms.

Computer screens resembled the paper forms but did not represent a one-to-one correspondence. The 'medical/dental history form', for instance, in the EagleSoft practice management program resembled the paper form; however, the treatment plan in most systems was typically combined with the display of the hard tissue chart and not available as a standalone form, with one exception (EagleSoft). All dental software packages used were able to display planned procedures in the hard tissue chart using graphical symbols, but this was not always done in paper charts. None of the software applications offered an analogue to the routing slip.

The consolidated cultural and physical models

The cultural model shows how values, constraints and influences relate to each other and to the participants in the work process. The consolidated physical model shows the layout of the workspace, how equipment and devices are arranged in the work environment and how dental team members use the space during their work. We will not discuss these models as they are outside the scope of this paper.

Breakdowns

Breakdowns often present natural opportunities for process improvement, regardless of whether technology is used or not. In addition, comparing all breakdowns at once reveals patterns of which type of breakdowns occurred most frequently. As Table 3 shows, we observed a total of 27 breakdowns. The vast majority of those, 17, were found in the sequence model. Seventeen of the breakdowns, or 63%, were related to technology. Most of those (14) were observed during digital imaging procedures, specifically while taking digital X-rays.

We observed 13 breakdowns related to the recording or retrieval of information. In several instances, a record format (either on paper or the computer) did not have an obvious place to record a certain type of data, for instance periodontal mobility measurements or DiagnoDent readings. At other times, there were breakdowns in retrieving existing information, for instance when an old patient chart was hard to read. Breakdowns also occurred when it was impossible to record information at the point and/or time of capture.

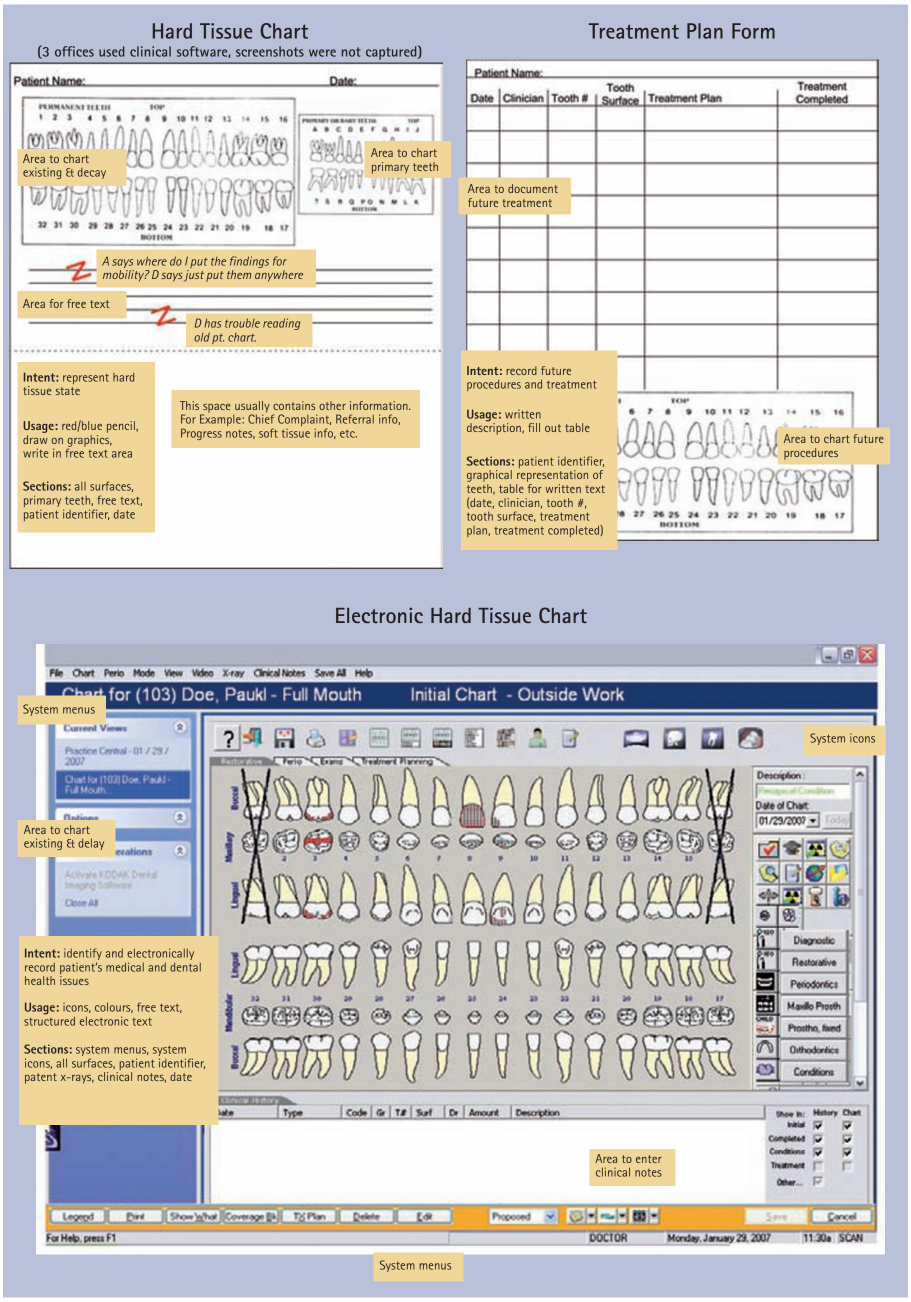

Fig. 2 Excerpt of the consolidated artifact model. A collection of some of the most important artifacts

The affinity diagram

The affinity diagram is a categorised, multi-level hierarchy of all insights, design ideas, breakdowns, useful quotes and questions developed by the researchers during the interpretation session. Our affinity diagram contained five main themes: communication, information, patient chart, technology and office operations. We briefly discuss relevant aspects of the five themes.

1) Communication

Five main qualities characterised communication in our study: universality, multiple channels, unobtrusiveness, timeliness and understandability. We briefly discuss these qualities below.

- *Universality*: as evident from our analysis, all dental team members communicated with each other and the patient. Because supporting these communication links was so important, offices had installed specialised devices and software for this purpose. For example, offices used colour-coded lighting systems, sound systems, and/or instant messaging
- *Multiple channels*: offices used a rich array of channels for communication. Verbal exchanges were frequently observed, but were by no means the

Table 3 Breakdowns

Number	Model	Breakdown	Imaging?	Comment
1	Artifact	A can't find places to put things in the chart: 'The photocopier cut off the labels to the chart spaces'		Found on periodontal chart
2	Artifact	A says where do I put the findings for mobility, D says just put them anywhere		Found on hard tissue chart
3	Artifact	D has trouble reading old pt chart		Found on hard tissue chart
4	Cultural	No one at front desk, no password, no locked door, can see computer screens (pt chart and schedule), can take paper charts, not locked		
5	Flow	D thought tooth 3 but really tooth 30 (on image)	X	
6	Flow	Medical alert sticker not on chart, FD did it later		
7	Flow	No place for DiagnoDent readings in practice management system		
8	Physical	D needs to switch patient, he doesn't have same tools in both ops		On model, breakdowns 8 and 9 were combined as lack of equipment in all operatories
9	Physical	D has to move laptop with X-ray and sensor to office to switch pt, turn off office lights	X	
10	Physical	The D had to stand up or move to use the mouse or keyboard		
11	Sequence	D writes notes on napkins (to be put in chart, discussed with H later)		
12	Sequence	H had to restart record mode on sensor for X-ray	X	
13	Sequence	D says with crc you need lower levels which is 'touchy' describing intermittent problems with X-ray machine	X	On model, breakdowns 12 and 13 were combined as X-ray equipment unreliable
14	Sequence	X-ray equipment unreliable – had to take multiple times	X	
15	Sequence	While H was taking intraoral images, foot pedal did not work, she had to freeze the pictures with the mouse	X	
16	Sequence	2nd bitewing didn't take because of smoke signal	X	
17	Sequence	H had to take bite twice because of bad first image	X	
18	Sequence	Pop-up on computer about staying connected interrupts office flow		
19	Sequence	At end of day they would put in information that they weren't able to do while the patient was there		
20	Sequence	D tries to write on sheet on top of laptop keyboard, but that moves the mouse cursor so he has to move the sheet beside him		
21	Sequence	D used DiagnoDent twice because composite restoration generated false reading		
22	Sequence	FD came in during exam to get HIPAA form to obtain pt's address		
23	Sequence	X-ray are not labelled with tooth numbed automatically; way of entering that information is too cumbersome	X	
24	Sequence	When taking X-rays has to touch computer each time	X	On model, breakdowns 23, 24, 25 and 26 were combined as too many steps in digital X-ray process
25	Sequence	A has to walk/push 4 different buttons to get X-ray	X	
26	Sequence	Too many steps in digital X-ray process	X	
27	Sequence	H walks 4 places to take X-ray	X	

Abbreviations: A = assistant; D = dentist; H = hygienist.

only methods for communication. Team members used a variety of gestural, postural and behavioural cues during communication. Indirect exchanges occurred through specialised communication devices, computer-based communications programs, written and other hardcopy artifacts, or object placement

- *Unobtrusiveness*: the colour-coded lighting system as well as many of the verbal and written exchanges, were, for the most part, very unobtrusive. This unobtrusiveness was driven both by patient needs and privacy/confidentiality requirements. Communications were sometimes made unobtrusive through the use of medical terminology, which the patient was assumed not to understand
- *Timeliness*: many communications had certain requirements for timeliness. One office set a 10 minute time limit for the response of the dentist to a non-verbal cue; another office marked finished procedures as 'completed' as soon as possible
- *Understandability*: a clear need for understandability, especially on the part of the patient, required dental team members to formulate communications in certain ways. However, understandability was also an issue

among dental personnel, as evident from a hygienist's comment about her deteriorating handwriting.

2) Information

Information was the essential content of the work process. Some data were maintained in duplicate or triplicate, for instance treatment information on treatment plans, tooth charts and routing sheets. Information was duplicated on paper, on the computer or both. Redundancy seemed to enhance the staff's perception of information integrity, as well as of thoroughness. However, we also observed a large amount of temporary data which was discarded after various life spans. Much of that transitory information did not make it into the patient chart, but rather appeared to enhance recall during later stages of the patient visit. Transient paper notes were used even in the most highly computerised office.

All members of the dental team were responsible for recording and managing information. Everyone entered clinical information such as treatment plans and progress notes into the chart and all but the dentist (who dictated findings) recorded findings during charting.

Easy access to information was an important aspect of workflow. Certain information, for instance the day's schedule, was posted strategically at key points in the office. Some offices posted clinically relevant information permanently.

3) Patient chart

The patient chart is a subset of 'information', but plays such a key role that it has its own theme. The patient chart is a multimedia document that combines text, numbers, graphical schemas and symbols, and a variety of images such as photographs and radiographs. Colour was used to encode information in multiple ways; sometimes it was used to identify the author. Sometimes it denoted types of data or stage of treatment. Graphical representations played an important role considering they were used to gain a quick overview of the patient's hard tissue status and problems. In some offices, graphical annotations substituted for treatment plans written as text.

Participants commented that clinical documentation should match the data gathering process, but that was not always the case. For instance, radiographs were not automatically tagged with the appropriate tooth numbers by the software, and many clinicians' sequence of steps in performing patient examinations did not always follow the order of information on the examination form(s).

Whether, and if so, when, information was recorded varied. Sometimes findings that were within normal limits were not recorded at all. Treatment plans were often changed, but those changes were not always recorded on the form containing the original treatment plan. At other times, information relevant to clinical care seemed to get lost. Information was rarely recorded in the patient chart when team members were examining/treating the patient, except when a third party was available for transcription. When that was not the case, information was recorded as soon as possible or practical in the chart, or temporarily on napkins and tray sheets.

4) Technology

Technology, specifically computer technology, was pervasive throughout all offices, but far from ubiquitous. All offices in the study had at least one computer and eight of the offices had at least one operatory equipped with a workstation and digital radiography capabilities. Some technologies, such as digital radiology sensors, monitors for patient education and voice input, were only available in some operatories, despite the fact that they were needed in most or all operatories.

Computers were seen as helping to improve the capabilities of individuals and/or the whole dental team, and digital imaging technology was considered to enhance diagnostic capabilities. Despite deriving several advantages from computer technology, some offices felt that they were not exploiting its capabilities fully. The level of technology literacy clearly influenced the degree to which that was the case.

As evidenced by the large number of breakdowns related to technology, computers clearly 'got in the way' of performing common tasks. They tended to interrupt the workflow, cause rework and increase the number of steps in a work process. Even viewed at a more general level, technology had problems. For instance, some technology did not have all the functions needed, did not integrate well with existing equipment and required workarounds.

5) Office operations

Office operations were highly complex and several major themes emerged. The office schedule was central because it influenced patient flow and required resources (such as materials and personnel). Office operations were constrained by the generally small size of the operatories. Auxiliary personnel often shared decision-making in the clinical workflow. Some dentists developed treatment plans with their hygienist and in other cases, assistants and hygienists made treatment planning decisions which the dentist simply signed off on.

Lastly, factors other than clinical considerations influenced the development of treatment plans. Acute pain, high priority given to treating children, insurance constraints, patients' lack of interest and dental phobias were examples of factors that impacted the treatment plan. Time constraints sometimes limited the degree to which treatment plans were refined, or compelled dentists to start on treatment during the first patient visit.

DISCUSSION

The results of this study are a rich and comprehensive description of workflow and information management during dental examination and treatment planning appointments in the US. It confirms some of the findings from earlier, primarily case-based studies of dental practice and adds insights gained from a broader and more comprehensive and systematic ethnographic data collection approach. As such, it heeds several calls for a more in-depth understanding of the socio-technical context prior to designing information systems in healthcare.[17–19]

Several major areas in which dental software could be improved in supporting initial examinations and treatment planning have emerged from our results:

Collaboration. As this study showed, dental personnel collaborate extensively and intensively during initial examination and treatment planning appointments. However, dental software supports this collaboration only in a relatively shallow manner inasmuch as any team member can walk up to a clinical workstation and modify a patient record (we did not observe any participant logging in or out of a workstation.) No software application made explicit who contributed what data to a patient record, what state the data was in (eg preliminary information to be reviewed by the dentist), or what information needed special attention.

Workflow. The patient's flow through the appointment was complex and unpredictable. Routing slips used in some offices clearly showed a need to track the patient through the many stages and aspects of the appointment. None of the software, however, provided the equivalent of a routing slip. A software-based routing slip could provide useful information in a format more flexible than the paper slip, for instance the chief complaint, progress of data gathering, diagnostic tests/tasks to complete, referrals, prescriptions and patient education interventions. Another aspect of workflow is the number and type of steps to complete a specific task, such as in digital radiology. As our study showed, taking a digital radiograph had many more steps and breakdowns than taking a conventional one. System vendors should examine those workflows in detail and explore possible improvements, for instance through better hardware/software integration.[20]

Communication. Smooth workflow and collaboration heavily rely on effective and efficient communication. Dental software supported few, if any, communication requirements in the office, as evidenced by the use of third-party communication software (eg, Smoke Signals, audio alerting software). While software clearly cannot, and should not, replace all communication, it could provide better support than it does now. One logical approach would be to integrate Smoke Signal-like function into dental software.

Information design and presentation. Despite their limitations, paper-based charts provide significant flexibility in information design and presentation. The hand-drawn symbols and markings on tooth diagrams are a rich, flexible and useful method of representing information. Although some dental software provides the capability for free-hand annotation, most applications' functionality is much more rigid. In addition, dental software breaks apart information that is much more cohesive on paper[21] and requires significant navigational overhead as a consequence. These findings argue for developing a much better fit between the requirements of a task and how the needed information is presented.

Information content. In multiple instances, practice management systems lacked the capability to accommodate a specific type of data (eg DiagnoDent readings). This observation parallels findings in a recently published study[21] that found significant mismatches in information content between paper- and computer-based patient records in general dentistry. While some practice management systems provide the capability to create user-defined fields, those fields are typically not well integrated with other patient information. Information content requirements for dental software will be in a state of constant evolution; however, it may be worthwhile to consider designing more flexible approaches to adding new types of data to patient record formats.

Data entry. Data entry worked most efficiently when someone was available to transcribe dictations. In lieu of that, dental team members used a variety of workarounds. This finding, as well as those from our survey on clinical computing,[5] strongly argue for improved interfaces to allow direct and straightforward data entry by clinicians. In addition, software functions should attempt to accommodate the flexibility in sequencing, granularity and comprehensiveness with which clinicians enter data.

Our study was conducted in the USA; however, we believe our results can provide insight into designing dental software to be used in any country. Our US sample is similar to British dentists in that more than half of the dentists in England work in small practices with one or two dentists.[4] Also over half of dentists surveyed in Wales either employ a hygienist or a hygienist-therapist.[22] Some roles and steps in the care process may differ, however office communication and organisation is still key for providing quality care.

In general, our observations portrayed the dental offices we visited as highly complex, collaborative and efficient work environments. Technology implementation in such settings is fraught with a high risk of disrupting the delicate operational balance and impacting workflow and productivity negatively. Technology clearly had its uses and utility, but its drawbacks and disadvantages were readily apparent. The single most significant finding regarding technology was that over 60% of the 27 breakdowns we observed were associated with technology. Poor integration of technology, already discussed elsewhere,[20] was evident in many respects. The NHS should be aware that our study has uncovered problems with technology integration, usability and data management that have already been documented in Great Britain.[2,3]

This study had several limitations. The response rate was not as high as desired, the sample size was small and the study was completed in the context of a single geographic area. However, the characteristics of the sample in this study corresponded well to those of the much larger sample of our interview study,[2] which was also randomly drawn from general dentists across the US. We believe that the geographical limitations may have the potentially biggest effect in biasing the results of our study, because healthcare practitioners in a region tend to have similar practice patterns. In addition, we cannot be sure how much of the participants' behaviour, if any, was influenced by the Hawthorne effect. Despite these limitations, we believe this study has provided a relatively accurate view of the current workflow of initial examinations and treatment planning in general dental practices.

This study produced only a preliminary model of work in dental practice, and future work should validate, refine and augment the model. Specifically, the model should be extended to other geographic settings and types of appointments, as well as to specialties. A comprehensive model of dental work will be an excellent resource for many purposes in dental practice, research and education.

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