Big Data: How data can guide the scientific decision-making process

Professor Heiko Spallek
Faculty of Dentistry

Slides
Dentists Trust Dentists

adapted from @David // Armano darmano.typepad.com
Disclosures

I am

- the representative of the American Association for Dental Research to serve on the American Dental Association's Standards Committee on Dental Informatics (SCDI),

- chair of the ADA SCDI Working Group 13.1 on Educational Software Used in Electronic Media and Working Group 13.4 Use of Computer-Based Resources for Access to Information Supporting Oral Healthcare,

- until recently, Board of Directors of the Consortium for Oral Health Research and Informatics (COHRI),

- member of the Advisory Council, Institute for Oral and Systemic Health (IOSH) at the Marshfield Clinic,

- until recently, member of the Board of Directors for German startup company Everbase,

- inventor of the cloud-based software products CredentialKeeper and Curriculum Management Tool with financial interest in the commercialization of these products,

- member of the Advisory Board of the Collaboration on Oral Health Technology with representatives from the Universities of Michigan, Buffalo, North Carolina Chapel Hill and Pittsburgh,

- funded by NIH as principal investigator (MPI) with $2,488,348 for “A Clinic-Randomized Trial of a Clinical Decision Support System to Improve Dental Provider Delivery of Brief Tobacco Interventions and Quitline Referrals”
Big Data: How data can guide the scientific decision-making process

**Ideas**

Why record keeping?
Comparison: paper vs electronic
What do we collect?
What can we learn from it?
Data Cemeteries → Sources of Knowledge
Learning Health System
Barriers
Why do we keep records?

“1854 Broad Street Cholera Outbreak”
What do we collect?
HARD TISSUE EXAMINATION:

Right:

<p>| | | | | | | | | | |</p>
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</table>

RADIOLOGY REPORT:

FINDINGS: (All areas described in radiolucent / radiopaque terms)

- Radiolucency: 2D, 3D, 4D, 5D, 6M, 8D, H, 9M, H, 10M, 12M, 13M, 14D
- 31 AOEK, 12 AOEK
- Precedent: 2BD, 5DO
- 24H, 21D, 27H

IMPRESSIONS: (Differential Diagnosis of findings)

1. Prognosis
2. Pulpal bone loss
3. Abscess
4. Caries
5. Calculus

Student: [Signature]
Faculty: [Signature]
Date: 2/1/67

Hard tissue exam and radiology report
What data do we collect?

Dental Records: WORN—write once read never
Did it help?

Well...
How information systems should support the information needs of general dentists in clinical settings: suggestions from a qualitative study

Mei Song1, Heiko Spallek1, Deborah Polk2, Titus Schleyer1, Teena Wali1

Abstract

Background: A major challenge in designing useful clinical information systems in dentistry is to incorporate clinical evidence based on dentists' information needs and then integrate the system seamlessly into the complex clinical work process. The purpose of this study is to identify general dentists' information needs and the information sources they use to meet these needs. To meet the needs of dentists, researchers investigated information needs during treatment sessions. The main purpose of this study is to identify general dentists' information needs and the information sources they use to meet these needs. The overall goal of this study is to provide information on how information needs and information source use patterns can be used to improve the design of information systems.

Methods: A semi-structured interview was conducted with a convenience sample of 15 general dentists in the Pittsburgh area during treatment sessions. Interviews were transcribed, and interviews were transcribed to identify categories and themes regarding information needs and information source use patterns. Results: Two top-level categories were identified: informational needs and administrative needs. To meet the needs of dentists, researchers investigated information needs during treatment sessions. The overall goal of this study is to provide information on how information needs and information source use patterns can be used to improve the design of information systems.

Unmet information
- timely access to information on various subjects
- better visual representations of dental problems
- access to patient-specific evidence-based information
- accurate, complete and consistent documentation of patient records
Why did we want to have computers in the operatory?

Let’s ask the dentists.
# Clinical Computing in General Dentistry

<table>
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<tr>
<th>Feature</th>
<th>Percentage</th>
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<td>Data management</td>
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<td>Scheduling</td>
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<tr>
<td>Retrieval</td>
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<tr>
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<tr>
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<tr>
<td>Digital imaging</td>
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<tr>
<td>Efficiency</td>
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<tr>
<td>Intraoral charting</td>
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<tr>
<td>Patient education</td>
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<tr>
<td>Other</td>
<td>6%</td>
</tr>
<tr>
<td>Convenience</td>
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</tr>
<tr>
<td>Better communication</td>
<td>2%</td>
</tr>
<tr>
<td>Error reduction</td>
<td>1%</td>
</tr>
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</table>

**Abstract**

Objective: To determine the utilization of, opinions and attitudes toward clinical computing among 256 general dentists in active practice in the United States.

Design: Telephone survey of 256 general dentists in active practice in the United States.

Measurements: Interviews assessing practice characteristics and information technology infrastructure; clinical computing (features of practice, Internet use, and adoption of clinical computing); clinical computing infrastructure.

Results: Among the 256 dentists surveyed (89.6% response rate), 214 (83.6%) had computers at chairside, with 170 (74.6%) respondents having computers at chairside and access to electronic health records. Clinical information was stored predominantly on paper (62.6%); 1.8% of all general dentists entered most data, while 6% entered most data. Patient education and treatment plans were stored predominantly on paper. Auxiliary personnel, such as dental hygienists, auxiliary assistants, and nurses, used computers to enter and retrieve patient information.

Conclusion: Clinical computing is increasingly adopted in general dentistry. However, research must address usefulness and ease of use, workflow support, infection control, integration, and implementation issues.

Scheduling

Titanium Web
Chairs 1-5
Select Book
Thursday, 11 June 2015

Chair 1
8 AM
Truax, Gregory
0491338422

9 AM
Kwon, Vin
0491339300

10 AM
Ramos, Justin
0491234444

11 AM
Dentist

12 PM
Admin Meeting

1 PM

2 PM

3 PM

4 PM

Chair 2
8 AM
Salton, Martin
0498347324

9 AM
Smith, John
049143900

10 AM
Choplin, Andreas
0491723950

11 AM
DENTIST

12 PM
Admin Meeting

1 PM

2 PM

3 PM

4 PM

Chair 3
8 AM
Stephens, Megan
049143900

9 AM
Stephens, Lucy
049143900

10 AM
Stephens, George

11 AM
Smith, Harry
04915000

12 PM

1 PM

2 PM

3 PM

4 PM

Chair 4
8 AM
Sanchez, Miguel

10 AM
Sanchez, Miguel

11 AM
Sanchez, Miguel

12 PM

1 PM

2 PM

3 PM

4 PM

Chair 5
8 AM
Clayton

9 AM
Clayton

10 AM
Clayton

11 AM
Clayton

12 PM

1 PM

2 PM

3 PM

4 PM

Chair Maintenance

Titanium Appointment Book
What data do we collect?

WORN—write once read never
A Qualitative Investigation of the Content of Dental Paper-based and Computer-based Patient Record Formats

Titus Schleyer, DMD, PhD, Heiko Spallek, DMD, PhD, Pedro Hernández, DMD

– developed a base-line dental record (BDR) from several paper records and textbooks
– compared BDR with information content of each PMS

Measurements: We calculated frequency counts of BDR categories and data fields for all paper-based and computer-based record formats, and cross-mapped information coverage at both the category and the data field level.

Results: The BDR had 20 categories and 363 data fields. On average, paper records and CPRs contained 14 categories, and 210 and 174 fields, respectively. Only 72, or 20%, of the BDR fields occurred in five or more paper records. Categories related to diagnosis were missing from most paper-based and computer-based record formats. The CPRs rarely used the category names and groupings of data fields common in paper formats.

Conclusion: Existing paper records exhibit limited agreement on what information dental records should contain. The CPRs only cover this information partially, and may thus impede the adoption of electronic patient records.

### Dental School

**Dentist**

**Vendor**

---

### MEDICAL HISTORY

**PHYSICIAN’S NAME**

**DATE OF LAST PHYSICAL EXAM**

**AGE**

**DO YOU HAVE OR HAVE YOU HAD ANY OF THE FOLLOWING - INDICATE WITH A (✓)**

- Arthritis
- Asthma
- Diabetes
- Heart disease (excluding hypertension)
- Hypertension
- Lung problems
- Mental health problems
- Osteoporosis
- Psychiatric problems or hospitalization
- Skin problems
- Stroke
- Tuberculosis
- Ulcer or caustic
- Viral infection
- Other

Describe any current medical treatment including drugs taken, even though not listed above...

---

### RESPIRATORY (LUNGS)

- **Tuberculosis**
- **Pneumonia**
- **Bronchitis**
- **Asthma / Wheezing**
- **Persistent Cough**
- **Other:**

### GASTROINTESTINAL

- **Kidney Disease**
- **Kidney Transplant / Dialysis**
- **Diverticulosis / Diverticulitis**
- **Liver disease**
- **Other:**

### HEART / BLOOD VESSELS

- **Rheumatic Fever**
- **Heart Murmur**
- **Chest Pain**
- **Heart Attack**
- **Shortness of Breath**
- **Swelling of Ankle**
- **High / Low Blood Pressure**
- **Congestive Heart Disease**
- **Aneurysm**
- **Heart Surgery**
- **Pacemaker**
- **Other:**

### BLOOD / LYMPH / IMMUNE

- **Blood Transfusion**
- **Hemophilia**
- **Anemia / Sickle Cell**
- **HIV Positive**
- **AIDS**
- **Other:**

### ENDOCRINE (GLANDS)

- **Diabetes**
- **Thyroid Trouble / Goiter**
- **Weight Change**
- **Hypertension**
- **Other:**

### GENERAL

- **Tired Easily**
- **Weakness**
- **Sweaty**
- **Persistent Fever**
- **Other:**

### OTHER

- **Radiation Therapy**
- **Chemotherapy**
- **Tumor or Growth**
- **Cancer**
- **Alcohol Use**
- **Tobacco Use**

---

The University of Sydney
### Baseline Dental Record (BDR) source

<table>
<thead>
<tr>
<th>BDR Categories</th>
<th>Dentists</th>
<th>School</th>
<th>Vendors</th>
<th>Text Books*</th>
<th>CPRs</th>
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<td>0</td>
<td>8</td>
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<tr>
<td>Radiographic history and findings</td>
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**Systemic diagnoses**

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**Treatment plan**

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<td>7</td>
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**Progress notes**

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### Total fields

- 367
- 85
- 217
- 177
- 176
- 207
- 280
- 174
- 233
- 230

### Total categories

- 150
- 254
- 90
- 211

*No numbers of data elements are reported for textbooks because they individually only cover a portion of the dental record.*
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<th>Data Type</th>
<th># of Data Elements</th>
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<td>Physician information</td>
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- Chief complaint: 18
- Medication history: 18
- Medical history: 6
- Dental/social history: 2
- Hard tissue and periodontal chart: 6
- Intraoral soft tissue examination: 2
- Extraoral head and neck examination: 6
- Temporomandibular joint/occlusion: 7
- Radiographic history and findings: 18
- Physician information: 6
- Alert/Summary box: 2
- Medical history update: 6
- Consultations: 7
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<td>Medical history update</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Consultations</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>313</td>
<td>39</td>
<td>98</td>
<td>80</td>
<td>77</td>
</tr>
</tbody>
</table>
Was it cheap?

cost of health information technology
Costs of Health IT: Beginning to Understand the Financial Impact of a Dental School EHR

100 DMD + 30 DH students; 100,000 patient visits/a dental school

- Initial acquisition:
  - between US$ 524,523 and US$ 2,503,971

- Ongoing operations/a:
  - between US$ 631,816 and US$ 848,105

Watch video: https://vimeo.com/fdim/spallek-cost-of-health-it
What Data Can We Collect?

some more optimistic remarks
What data can we collect?

Classes of data
1. structured in traditional databases
2. unstructured, e.g. images, video, voice, GIS
3. Internet of Things (IoT)

Internet of Things (IoT)

Figure 1. The Internet of Things Was “Born” Between 2008 and 2009

<table>
<thead>
<tr>
<th>Year</th>
<th>World Population</th>
<th>Connected Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>6.3 Billion</td>
<td>0.08 More connected devices than people</td>
</tr>
<tr>
<td>2010</td>
<td>6.8 Billion</td>
<td>1.84</td>
</tr>
<tr>
<td>2015</td>
<td>7.2 Billion</td>
<td>3.47</td>
</tr>
<tr>
<td>2020</td>
<td>7.6 Billion</td>
<td>6.58</td>
</tr>
</tbody>
</table>

Source: Cisco IBSG, April 2011
Internet of Medical Things (IoMT)

1. Attach the AliveCor Heart Monitor

- LOGO DIRECTION
- TOP OF DEVICE

Welcome, Jane

Rest fingertips on metal electrodes as illustrated below.

ECG Analysis
Print
Email
PDF
Cancel
Internet of Dental Things (IoDT)

WORLD’S FIRST CONNECTED ELECTRIC TOOTHBRUSH W/ 3D MOTION SENSORS

Data gets pushed via Bluetooth®
Internet of Dental Things (IoDT)

Onvi says it has created the first smart video toothbrush

http://www.bizjournals.com/chicago/news/2016/12/06/chicago-startup-onvi-smart-video-toothbrush.html#i1
What can we learn from aggregated data?

Big Data – just hype?
Data Cemeteries ➔ Sources of Knowledge

"ensuring that electronic repositories become valuable resources rather than expensive investments that are quickly ignored"


Steps
- interoperability = connectedness
- standardization
- data stewardship

We need to educate decision makers about this!
Atul Gawande on the potential of information for health

kinds of information that matter to your health and well-being over time, information about the state of ...
- your internal systems, e.g. imaging, lab-test results
- your living conditions, e.g. housing, environment
- the care you receive, e.g. medications, treatments
- your behaviors, e.g. sleep, exercise

“The potential of this information is so enormous it is almost scary.”

What can be done with Big Data?

By integrating claims, clinical, socio-demographic and care management data, you receive both a retrospective and prospective view of your patients and your patient populations.

Clinical data of nearly 50 MILLION PATIENTS
Longitudinal claims data of 20 YEARS
Claims data covering over 109 MILLION LIVES

› Identify at-risk patients earlier
› Preserve patient health
› Reduce costs
› Prevent complications

Mayo Clinic (59,000 employees) + UnitedHealth Group ($122 billion corporation) + Optum Labs:

$300m research study over 5 years:
repeated in hours, same result
Why data is a key economic resource

“The fact that data can be shared, used and reused an unlimited number of times (it is ‘non-rivalrous’ in consumption) makes it an especially valuable resource.”

Data Availability and Use

Productivity Commission Issues Paper

April 2016
.. the value of publicly funded datasets is maximised where (de-identified) data are freely available to researchers, where data is updated regularly and where investment in good data management and curation practices ensure that data is FAIR (Findable, Accessible, Interoperable, Reusable). Conversely, their value is greatly diminished if access is difficult or denied, or if the data are not curated well.

For example, oral (dental) and medical clinicians are unable to share crucial healthcare information about mutual patients in their care, resulting in sub-optimal patient outcomes$^{13,14}$.
Vision of a Dental Education Data Warehouse

Credit: Marc Triola, MD
Associate Dean for Educational Informatics
NYU School of Medicine
The Big Data Context: Dental Education

North America alone
- 60+ dental schools
- 20,000 dental students
- 500 residents
- 167,000 dentists
- 50,000+ patient visits/typical dental school/year

“big-data science for education”
“learning informatics”

The Patient Will See You Now: The Future of Medicine is in Your Hands
Eric Topol
The Big Data Context: Dental Education

Australia alone
- 9 dental schools
- 20,000 dentists

Sydney (WCOH)
- 500 dental students
- 371 residents, VDO & clinical educators
- 150,000 dental visits/yr

“big-data science for education”

“learning informatics”

The Patient Will See You Now: The Future of Medicine is in Your Hands

Eric Topol
We collect a LOT of Data in Dental Education

- Big Data and analytics can help us produce better dentists.
- Learning analytics methods to derive actionable knowledge from a sea of data.
- Patient health outcomes are the ultimate indicator of the effectiveness of dental education.

“There’s an entire industry devoted to measuring how important my research is, with impact factors of papers and so on. Yet, we don’t even collect data on how I am teaching.”

Carl Wieman, Nobel Prize winning physicist (Science Vol 340 April 19, 2013)
Examples: Professionalism, Admissions, Simulation

Does unprofessional behavior in medical school predict disciplinary actions by the state licensing boards?

M Papadakis et al NEJM 2005

Are DAT and GPA predictors for clinical performance?

Do virtual case simulations improve the quality of patient history taking by dental students?

Does simulation clinic performance correlate with the survival time of restorations?
Data Cemeteries ➔ Sources of Knowledge

‘Education Data Warehouse’
- comprehensive picture of all learners
- detailed information on the content of our curricula, assessments
- information about a person’s performance, strengths, weaknesses, interests, experiences
- model a student’s ‘educational genome’
- guide future learning

Marc Triola
Dental Education Data Warehouse for "personalized learning"
Continuous Improvements

Vision of a Learning Health System
Learning Health System (LHS)

*Health systems---at any level of scale---become learning systems when they can, continuously and routinely, study and improve themselves*

---

The *NEW ENGLAND JOURNAL of MEDICINE*
Perspective: Jan 3, 2013
“Code Red and Blue — Safely Limiting Health Care’s GDP Footprint”
Arnold Milstein, M.D., M.P.H.

…*U.S. health care needs to adopt new work methods, outlined in the Institute of Medicine’s vision for a learning health system*…
A Health System That Can Learn

- Every patient’s characteristics and experience are available for study
- Best practice knowledge is immediately available to support decisions
- Improvement is continuous through ongoing study
- This happens routinely, economically and almost invisibly
- All of this is part of the culture
The LHS Must Do This

A Problem of Interest

- Assemble Relevant Data
- Analyze Data
- Interpret Results
- Deliver Tailored Message
- Take Action to Change Practice
- Decision to Study

The University of Sydney
Not This

A Problem of Interest

- Decision to Study
- Assemble Relevant Data
- Analyze Data
- Interpret Results
- Take Action to Change Practice
- Deliver Tailored Message
- Journals?
How can we accelerate 17 years to 17 months?
Converting data cemeteries to sources of knowledge
What are the barriers?
Ownership of Data

“My Device, My Body, My Data
An Access Conversation with Hugo Campos

The Patient Will See You Now: The Future of Medicine is in Your Hands by Eric Topol

https://medium.com/access-matters/my-device-my-body-my-data-4e158f8dfcec
Data Stewardship

Your health and care records

The care.data programme - collecting information for the health of the nation

The care.data programme will bring together securely, health and social care information from different settings in order to see what’s working really well in the NHS and what could work better. Using data in this way is known as data sharing for purposes beyond direct care, information will only be shared if it will benefit patient care.

Failure to Heed Patients’ Privacy Requests Raises ‘Big Data’ Concerns in England: Offers Lessons for How Clinical Pathology Lab Test Data Should Be Protected in U.S.

Category: Compliance, Legal, and Malpractice, click daily home page, Laboratory Management and Operations, Laboratory News, Laboratory Operations, Management & Operations
Published: August 14 2015

National Health Service agency admits to releasing information on 700,000 patients who opted out of nation’s new centralized medical-information database

In the United States, the debate is ongoing about how healthcare data is used while at the same time protecting patient privacy. The outcome of this debate will be increasingly important for medical laboratories because—in order to deliver more value—labs will want to combine lab test data with other sources of clinical information.

NHS to carry on selling patients' medical data to insurance firms despite history of blunders over illegal use of the information

The NHS will continue to sell patients’ medical records to insurance firms

Data includes personal details of diagnoses, dates of birth and postcodes

Expert said proper checks were now in place to prevent misuse of records

By BEN WILKINSON FOR THE DAILY MAIL

The NHS will continue to sell patients’ medical records despite its woeful history of blunders over the illegal use of private data.

The Mail revealed in June that files had been sold to insurance firms and other companies without proper checks and balances.

The data – including highly personal details of patient diagnoses, dates of birth and postcodes – was used to help calculate insurance premiums.
Re-identification

We randomly sampled 5,000 numbers from our crowdsourced MetaPhone dataset and queried the Yelp, Google Places, and Facebook directories. With little marginal effort and just those three sources—all free and public—we matched 1,356 (27.1%) of the numbers. Specifically, there were 378 hits (7.6%) on Yelp, 684 (13.7%) on Google Places, and 618 (12.3%) on Facebook.

Garbage in Garbage Out

Social media for tracking disease outbreaks – fad or way of the future?

October 12, 2016 11:03am AEDT    Updated October 13, 2016 4:05pm AEDT

FT Magazine:  http://www.ft.com/intl/cms/s/2/21a6e7d8-b479-11e3-a09a-00144fabea0c.html
Nature:  http://www.nature.com/news/when-google-got-flu-wrong-1.12413#/fever
The Conversation:  https://theconversation.com/social-media-for-tracking-disease-outbreaks-fad-or-way-of-the-future-66401

FEVER PEAKS
A comparison of three different methods of measuring the proportion of the US population with an influenza-like illness.
Analyzing qualitative data

qualitative data = hows & whys

transform qualitative $\rightarrow$ quantitative: shallow shadow of original form
e.g. toothache

humans explain context when communicating

computers get context during design from engineers

Stephen Cohen on Big Data: Full talk from Wired 2012
https://www.youtube.com/watch?v=Vw2RMun-sS
Privacy “big-data authoritarianism”

http://en.wikipedia.org/wiki/Future_Attribute_Screening_Technology
Super AI
Bostrom, Nick: Superintelligence: Paths, Dangers, Strategies

Artificial intelligence and nanotechnology 'threaten civilisation'

Artificial intelligence will become strong enough to be a concern, says Bill Gates

"Artificial intelligence might be a threat to humans but not for the reasons you think"
Nigel Shadbolt

Experts including Elon Musk call for research to avoid AI 'pitfalls'

When fridges attack: the new ethics of the Internet of Things

Elon Musk: artificial intelligence is our biggest existential threat
Current and Future Work

What would an EHR system look like that dentists suddenly can’t live without?

Paraphrased from:
When lead engineer of I.B.M.’s Watson’s health team, Eric Brown, was asked what the equivalent of the “Jeopardy!” victory would be in medicine, he responded:

“It’ll be when we have a technology that physicians suddenly can’t live without,”

http://www.nytimes.com/2015/03/22/opinion/sunday/why-health-care-tech-is-still-so-bad.html?_r=0
Clinical Decision Support Systems

A Clinic-Randomized Trial of a Clinical Decision Support System to Improve Dental Provider Delivery of Brief Tobacco Interventions and Quitline Referrals

Principal Investigator: Brad Rindal, Healthpartners and Heiko Spallek, University of Sydney
Funding Source: National Institute of Dental and Craniofacial Research (NIDCR) - U01DE026135
Award Period: 8/2/2016 – 7/31/2020
Award Amount: $2,488,348

Cloud-based Knowledge-as-a-Service directly integrated into a dental EHR to support dental providers’ delivery of tobacco cessation interventions

https://projectreporter.nih.gov/project_info_description.cfm?aid=9156468
Cloud-based Dental EHR

Dental schools at the Universities of Michigan, Pittsburgh and North Carolina have partnered with Internet2 and ICE Health Systems to develop a cloud based electronic health record for dental education.

ICE Health Systems on Internet2

http://www.internet2.edu/products-services/cloud-services-applications/ice-health-systems/

Patients and care providers can all view the record for emergencies and consultations.
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- Seth Weinberg, BA, MA, PhD
- Debrah Weiner, MD
- Robert Weyant, MS, DMD, DrPH
- many more…
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Today’s slides: