SURGICAL ROBOTS IN CONTEMPORARY DENTAL PRACTICE

TRUST IN DENTISTS AND THE IMPLEMENTATION OF SURGICAL ROBOTS

A Thesis Prospectus submitted to the Department of Engineering and Society
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By

Nir Isaac Diskin

July 31, 2020

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS
Catherine D. Baritaud, Department of Engineering and Society
Patricia C. Click, Department of Engineering and Society

Since its first documented occurrence in 1985, robot-assisted surgeries have become increasingly prevalent in the medical field (Lanfranco et al., 2004, p. 15). Robotic systems boast numerous benefits for surgeons including increased surgical dexterity and precision, improved visualization, and ergonomic positioning. These advantages enable surgeons to perform technically challenging surgeries considered previously unfeasible (Lanfranco et al., 2004, p. 16). Outside of the technical benefits, the reduced invasiveness of these systems have intrinsic marketing value for physicians (Lanfranco et al., 2004, p. 1). The innovation of robotic surgical systems comes at a time when public trust in doctors has been steadily diminishing. Over a 50-year period, public confidence in healthcare professionals fell from 73% in 1966 to 34% in 2012 (Blendon et al., 2014, p. 1570). A 2017 meta-analysis found a direct correlation between a patient's trust in their healthcare provider and the outcome of their treatment, highlighting the tangible effects of the erosion of trust (Birkhäuer et al., 2017, p. 6). The increased use of surgical robots in healthcare stands to change the patient-physician relationship, a factor seemingly unconsidered in the adoption/development of this technology.

While the dental field had been relatively untouched by developments in surgical robotics compared to other medical professions, the first dental robot became commercially available in 2018 (Coutrè, 2019). My technical project and tightly-coupled STS research aim to provide a better understanding of the role of surgical robots in the dental field and the associated implications for trust between patients and their dentists. The technical portion will consist of a state-of-the-art report describing the usage of and operations associated with surgical robots in contemporary dental practice as well as an overview of future innovations of dental robotics currently under development. The tightly-coupled STS research will explore the concept and formation of trust between patients and their physicians through the application of the Rogers et al. (2014) Diffusion of Innovation model to multiple medical innovations. The findings of this analysis will then be used to predict the impacts increased use of surgical robots in dentistry will have on patient-dentist trust.

SURGICAL ROBOTS IN CONTEMPORARY DENTAL PRACTICE

The first documented use of surgical robots is use of the PUMA 560 robot, alongside computed tomography (CT) imaging, to precisely place a needle during a brain biopsy (Rawtiya et al., 2014, p. 1700). In the years that followed, the list of procedures involving robots grew at a rate "consistent with improvements in technology and the technical skill of surgeons" (Lanfranco et al., 2004, p. 15). The primary motivations for the adoption of surgical robots are advertised technical and economic benefits.

These surgical robots enable surgeons to perform minimally invasive surgeries which reduce the size of incisions, risk of infection, patient pain, postoperative immune dysfunctionality, and overall length of hospital stay (Lanfranco et al., 2004, p. 15). In delicate surgeries, the precision of these systems effectively minimizes human error associated with unintended motion (Rawtiya et al., 2014, p. 1702). These benefits also doubled as potent advertising for clinics with physicians using surgical robots to draw in new patients (Lanfranco et al., 2004, p. 16). However, this technology is not infallible. Their mechanical nature prevents haptic feedback and confuses natural hand-eye coordination. In other words, these machines have no way of effectively passing along force and tactile information that a surgeon would normally receive through their sense of touch and the use of a 2D monitor to guide surgical tools can be counterintuitive (Lanfranco et al., 2004, p. 15). Additional advantages and disadvantages of these systems are identified in Table 1 on page 4.

Table 1: Comparison of Conventional and Robotic Surgery: A comprehensive list of the advantages/ disadvantages associated with robotic-assisted surgeries (Lanfranco et al., 2004, p. 17).

	Conventional Laparoscopic surgery	Robot-assisted surgery
Advantages	Well-developed technology	3-D visualization
	Affordable and ubiquitous	Improved dexterity
	Proven efficacy	Seven degrees of freedom
		Elimination of fulcrum effect
		Elimination of physiologic tremors
		Ability to scale motions
		Micro-anastomoses possible
		Tele-surgery
		Ergonomic position
Disadvantages	Loss of touch sensation	Absence of touch sensation
	Loss of 3-D visualization	Very expensive
	Compromised dexterity	High start-up cost
	Limited degrees of motion	May require extra staff to operate
	The fulcrum effect	New technology
	Amplification of physiologic tremors	Unproven benefit

These shortcomings become much more concerning when considering the inconsistency in regulation of robotic surgery training. Currently, training to operate surgical robots is an unstandardized process with some programs requiring hours of online training and practice with cadavers while others leave the surgeon to decide for themselves what they need to successfully perform robot-assisted surgery (Center for Devices and Radiological Health & Office of Surveillance and Biometrics, 2013, p. 2–3) Despite these limitations and concerns, the use of robots in the operating theatre continues to grow in popularity.

CATEGORIZATION OF SURGICAL ROBOTS

The industry accepted definition of surgical robot is “a powered computer-controlled manipulator with artificial sensing that can be reprogrammed to move and position tools to carry out a range of surgical tasks” (Davies, 2000, p. 129). The development of these robots is driven by advancements in the miniaturization of materials and the innovators’ desire to increase surgical capabilities and minimize procedural invasiveness. Two major groups of robotic surgical systems currently exist. The first group, known as telemanipulaters, are not truly autonomous. A surgical robot of this type typically has a master console that acts as the control center for the robot's "slave" mechanical arms. The surgeon monitors and manipulates the robot using 3D endoscopic imaging. This setup also includes a tableside cart which serves as the base of the arms/surgical tools of the robot and holds relevant supporting equipment such as suction pumps, electrosurgical units, and guiding lights (Center for Devices and Radiological Health, 2019; Korb et al., 2004, p. 722). The relationship between the robotic elements are shown in Figure 1. These semi-autonomous systems process embedded sensor information to control the manipulator system, for example, automatically guiding the endoscopic camera or suppressing trembling of the surgical arms.

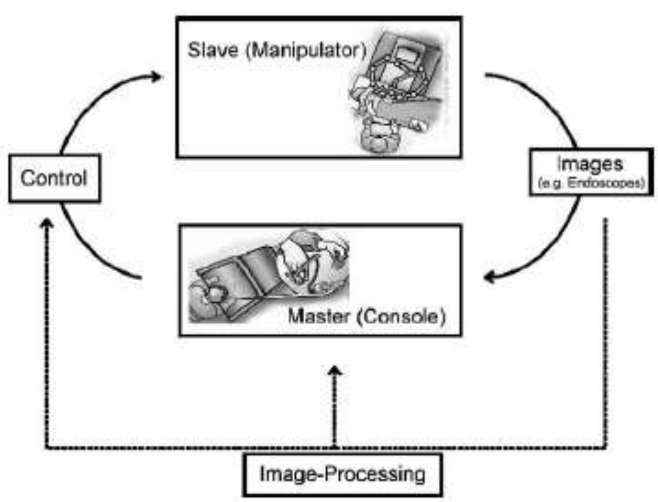

Figure 1: Semi-autonomous Surgical Robot: General workflow of a telemanipulator surgical robot (Korb et al., 2004, p. 723).

The second group of surgical robots are preprogrammed. Robots of this type execute their preoperational plan with minimal intervention from the supervising physician. The role of the surgeon becomes one of an overseer, providing virtual confirmation of each successful step to enable the robot to continue the operation (Korb et al., 2004, p. 722-723). In some cases, the surgeon plays a more active role, interactively programming the robot throughout the surgery and adjusting the position of its surgical tools to perform the new tasks (Rawtiya et al., 2014, p. 1704).

Both groups of robots are applied in numerous specialty fields of medicine including orthopedics, urology, cardiology, neurosurgery, and ENT-surgery (Korb et al., 2004, p. 723–726). However, despite their growing popularity, surgical robots have not been widely adopted in dentistry, with Professor of oral and maxillofacial surgery at Case Western Reserve University, Faisal Quereshy, speculating that the primary reason for the lack of adoption of dental robots is the general accessibility and visibility of the mouth (Coutrè, 2019). However, recent developments in dental surgical robotics may change the status of robots in dentistry. The founder of Miami-based robotics healthcare startup Neocis, Alon Mozes, describes the current field as “a wide-open opportunity” (Coutrè, 2019). Interestingly, while patents for dental-specific telemanipulaters exist, preprogrammed surgical robots are the most prevalent category of robots in development for use in dental surgery (Suttin & Porter, 2016).

MULTIDIRECTIONAL GROWTH OF DENTAL ROBOTICS

Researchers at the Harvard School of Dentistry assessed that 17.6% of adverse dental effects can be attributed to physical mistakes made by dentists ranging from misplaced injections of anesthesia to root perforation during surgery (Obadan et al., 2015, p. 17). Preprogrammed surgical robots offer a solution which reduces reliance on the technical skills of the surgeon (Rawtiya et al., 2014, p. 1702). The rigidness of these robots make them particularly well-suited for maxillo-facial procedures which require the precise drilling and cutting of bones (Korb et al., 2004, p. 723).

Development of these robots follow a few different avenues. The first commercially available dental robot, Yomi, follows a standard surgical robotic setup as seen in Figure 2. In this configuration, the dentist physically guides surgical tools which they had interactively programmed at a nearby monitor. This system offers 3D CT imaging to assist in procedural planning and operation (Coutrè, 2019).

Figure 2: The First Dental Robot: Configuration of the Yomi dental robotic system (Parmar, 2017).

Other iterations of dental-specific surgical robots increase the autonomy of the surgical system. Recent developments in artificial intelligence have enabled robots to aid in clinical diagnosis and treatment planning (Khanna & Dhaimade, 2017, p. 164). A prime example of this type of robot, the Microbot is hailed as the future of endodontics. It is completely autonomous and aims to reduce the time and error commonly associated with endodontic surgery. It does so by assessing the status of the tooth and automatically prescribing and performing the drilling, cleaning, and filling associated with these procedures (Neha et al., 2017, p. 7–8; Rawtiya et al., 2014, p. 1702). This device is small enough to be mounted directly onto the teeth of the patient seen in Figure 3, providing 3D modelling of the root canal through which the surgeon can monitor progress (Neha et al., 2017, p. 7).

Figure 3: The Future of Endodontics: Microrobot mounted on the teeth of a dental patient (Neha et al., 2017, p. 8).

Following the trend of increased robotic autonomy, research has begun on dental-specific nanobots, a technological breakthrough which may lead to the development of the new field of “nanodentisitry” (Shetty et al., 2013, p. 50). These robots manipulate matter at the atomic level introducing multitudes of new opportunities with regard to noninvasive dental procedures. The applications of this technology range from permanently curing hypersensitivity through constant maintenance of oral health to complete orthodontic realignment in a single visit (Bhat et al., 2017, p. 68). Once these nanorobots have completed their tasks, they deactivate and are safe to swallow (Shetty et al., 2013, p. 51).

The dental robotics industry is rapidly developing. To understand the potential implications these innovations may have on society, a deliberate effort must be made to understand their capabilities. In a state-of-the-art report, I will provide an overview of (1) the uses of surgical robots in contemporary dental practice and (2) future directions of innovations in dental robotics currently under development.

TRUST IN DENTISTS AND THE IMPLEMENTATION OF SURGICAL ROBOTS

Public trust in healthcare professionals has been steadily diminishing over time. Between 1966 and 2012, public trust in physicians fell by approximately 40%, leaving only 34% of American adults with a "great confidence" in their healthcare providers (Blendon et al., 2014, p. 1570). A survey conducted by the International Social Survey Programme (ISSP) found the United States ranked 24th in the level of public trust in physicians out of the 29 participating industrialized countries (Blendon et al., 2014, p. 1571).

The levels of trust between patients and their physicians have observable impacts. Birkhäuer et al. (2017), a team of researchers under the psychology department at the University of Basel in Switzerland, analyzed 400 publications and 47 studies in a meta-analysis to determine if the level of a patient's trust in their physician had an effect on their health outcomes (p. 1). The analysis found a small-moderate correlation between trust and actual health outcomes, a moderate correlation between trust and patient self-rated health outcomes, and a large correlation between trust and overall patient satisfaction (Birkhäuer et al., 2017, p. 6). Patients with higher levels of the trust in their physicians were also more likely to be retained when going through taxing treatments (Graham et al., 2015, p. 664). Additionally, patients who trust their physicians tended to report, "more beneficial health practices, higher satisfaction and health-related quality of life, [and] better symptom-oriented subjective outcomes" (Birkhäuer et al., 2017, p. 9). These findings provide incentives for medical professionals who prioritize their patient's wellbeing to maintain/improve public trust in physicians.

UNDERSTANDING TRUST IN HEALTHCARE

Kvalnes, a contemporary Norwegian moral philosopher, defines trust as a function of ability, benevolence, and integrity (Kvalnes, 2017, p. 80). Actor Network Theory (ANT) (Hurtado-de-Mendoza et al., 2015, p. 330), a conceptual framework employed to analyze and understand relationships between entities with agency, is used to illustrate this concept as seen in Figure 4 on page 10. Exploring each of these factors individually will shed light on which has the most impact on trust between patients and their physicians.

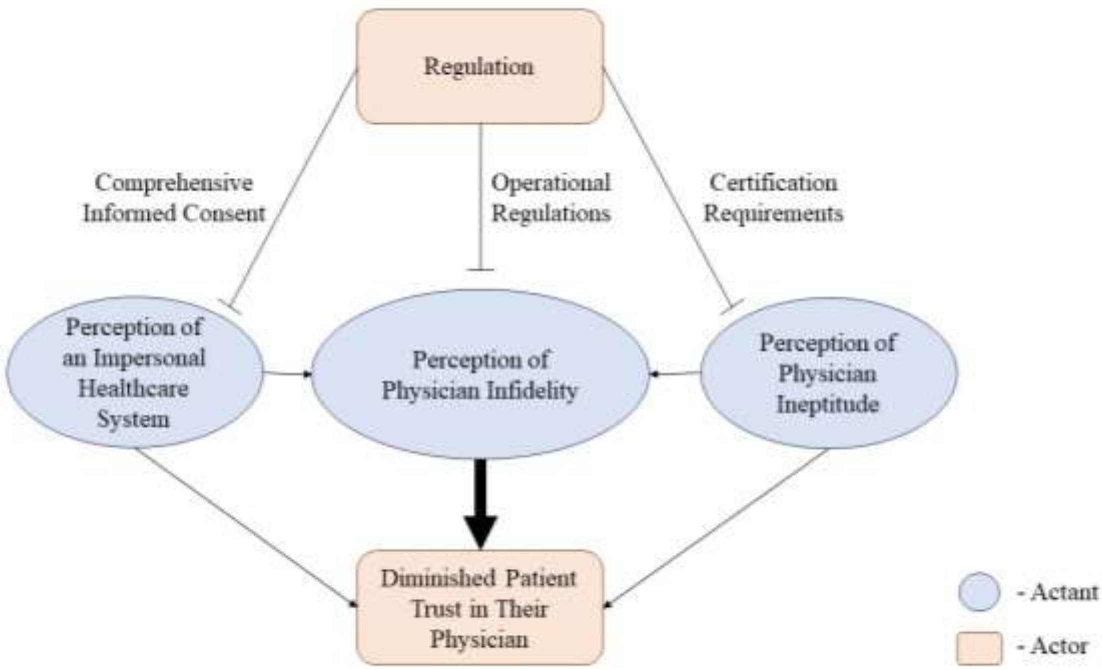

Figure 4: Analyzing Patient-Physician Trust Factors: An ANT network relating patient perceptions to patient-physician trust and the theoretical, inhibitory influence of the proposed regulatory solutions. (Diskin, 2020).

Ability is the most straightforward, referring to the technical competence of the physician. In essence, a physician who is perceived to be more capable is generally seen as more trustworthy. Interestingly enough, the same ISSP survey which found the United States to rank 25th out of 29 countries with regard to public trust in healthcare providers, also ranked the United

States as 3rd overall for patient satisfaction with their treatment (Blendon et al., 2014, p. 1571). This discrepancy between public trust of and public satisfaction with physicians implies the cause of the growing distrust does not primarily stem from physician ineptitude.

Benevolence refers to the interpersonal skills of the doctor, i.e. their ability to communicate effectively and form relationships with their patients. In an interview for *Medical Economics*, Stephen Post, director of the Center for Medical Humanities, Compassionate Care, and Bioethics at State University of New York at Stony Brook, speculates that the cause of the erosion of trust is the perceived impersonality of the modern medical system. He uses the amount of time physicians spend with their patients as a metric for measuring impersonality, citing how there is “very little time for clinicians to establish meaningful rapport with patients,” (Sweeny, 2018) However, studies have shown that the average time physicians spent with patients has averaged between 16-20 minutes for the past three decades (Rabin, 2014). In fact, the number of visits lasting 15 minutes or less dropped by 20% between 1992 and 2010 (Rabin, 2014). As public trust in physicians was still falling throughout this time period, these findings suggest that the time physicians spend with patients is also not the main cause of the diminished trust.

Finally, integrity refers to the fidelity of physicians. In the words of the medical professionals, Thom et al., at its core, “trust is the acceptance of a vulnerable situation in which the truster believes that the trustee will act in the truster’s best interests” (Thom et al., 2004, p. 125). From this perspective, distrust would be bred from a patient’s skepticism at the motives of their physicians. Increased access to medical information contributes to this distrust as patients arrive to their own conclusions regarding their health, second guessing physicians if their opinion differs (Sweeny, 2018). Physicians are often viewed as a monolith, which results in a single instance of predatory practices, such as hiking co-pays for office visits or declining

Medicaid/Medicare, potentially damaging a patient's perception of all healthcare professionals (Sweeny, 2018). Continuing with this line of argument, Blendon et al. (2014) wrote that one of the most prevalent grievances the public has with the healthcare system are the perpetually rising costs (p. 1572). Historically, one of the causes of this trend is the adoption of new, medical innovations by physicians who then use these advancements to justify raising procedural costs (Sarewitz & Woodhouse, 2003, p. 68). These practices, combined with the previously mentioned perceptions of physician ineptitude and impersonality, reinforce the perception of physician infidelity. As seen in Figure 4 on page 10, this patient perception seems to be the chief cause of the erosion of trust. To identify a solution to this issue and prevent further degradation of patient-physician trust, the motivations behind the adoption of medical innovations as well as their subsequent social effects must be understood.

THE DIFFUSION OF MEDICAL INNOVATIONS

As mentioned previously, the driving forces for the quick adoption of surgical robots by surgeons are primarily technical and economic. While a physician's success revolves heavily around technical and economic prowess, the profession is inherently social, a perspective seemingly unconsidered in the incorporation of this technology. The increased use of surgical robots in healthcare stands to change the patient-physician relationship. According to Morris (2005), a primary care physician and member of the Medscape Health Network, robotic surgery has revolutionary applications which change the capabilities of modern medicine (p. 74). He goes on to describe telerobotic procedures, in which a "surgeon operates from the surgeon's console, which is thousands of miles away from the slave robotic arm mounted on the patient; the surgeon's commands are relayed to the slave manipulator via fiber-optic cables" (Morris, 2005, p. 74). The implementation of any sort of autonomous robot inherently removes a layer of contact between the patient and the physician. This separation reduces the historically integral social aspect of healthcare. This sentiment is echoed in a 2018 survey, given by researchers at Embry-Riddle Aeronautical University in Florida, which found that participants generally did not trust an autonomous robot to perform any form of invasive procedure (Milner et al., 2020, p. 6). If patients do not like the idea of it, why are physicians adopting surgical robots?

To answer this question, we must look at the adoption of previous healthcare innovations. In his best-known work, *Diffusion of Innovation*, communication and social change scholar, Everett Rogers (2014) defines diffusion as "the process by which an innovation is communicated through certain channels over time among members of a social system (p. 3). He continues to define an innovation as "an idea, practice, or object perceived as new by an individual or other unit of adoption" (Rogers et al., 2014, p. 3). Originally applied to understanding the adoption of hybrid seed corn by Iowan farmers, the Innovation Diffusion Theory is now commonly used to study the adoption of technology and its spread between communities (Zhang et al., 2015, p. 3). This model can be applied to innovations in the healthcare industry to understand the factors behind the adoption, or lack thereof, of a given technology (Cain & Mittman, 2002, p. 5). Adopters of innovation have been broken into five categories by their relative time of adoption: innovators, early adopters, early majority, late majority, and laggards. These groups are represented as percentages of a whole population, following a normal distribution as seen in Figure 5 on page 14. Cain and Mittman (2002), researcher and director at the Institute of the Future, identified 10 critical dynamics of innovation diffusion which control the adoption rate of a given innovation (p. 5). These dynamics are: relative advantage; trialability; observability; communications channels; homophilous (similar) groups; pace of innovation/reinvention; norms, roles, and social networks; opinion leaders, compatibility, and infrastructure (Cain & Mittman, 2002, p. 5).

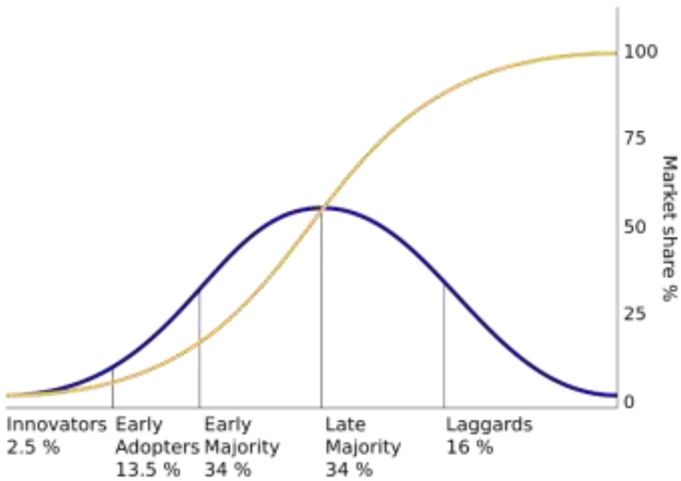

Figure 5: The S Curve: Categories of adopters according to the Diffusion of Innovation Theory (Cui, 2016).

This model will be used to analyze and understand the motivations behind the adoption of healthcare innovations which parallel the implementation of surgical robots with regards to changing the relationship between patient and physician. These innovations will range from technological, e.g. the computerization of medical records (Evans, 2016), to regulatory, for example, the implementation of the Affordable Care Act (Obama, 2016). The findings of these analyses will be used to identify historical trends in the adoption of healthcare innovations and their subsequent effects on the healthcare system. This information, paired with contemporary moral philosophy regarding the development of trust in healthcare, will be used to predict the broader social effects of the implementation of surgical robots in dentistry, focusing specifically on trust.

As the root cause of distrust in physicians by patients are the unclear motives of healthcare providers, the discretionary use of medical robots by surgeons must be limited.

Government regulation pertaining to the use and implementation of surgical robots must be created/updated and standardized with a specific focus on policies regarding informed consent, operational procedures, and surgical certifications to prevent a further decline in public trust in physicians (Figure 4).

My STS research project will be a scholarly article exploring the potential implications of the implementation of surgical robots in dentistry on the levels of trust between patients and their dentists.

WORKS CITED

Bhat, D., Bhandary, S., Naik, R., & Shetty, D. (2017). Robotics in dentistry: Fiction or reality. *Journal of Dental Research and Review*, *4*(3), 67–68.

Birkhäuer, J., Gaab, J., Kossowsky, J., Hasler, S., Krummenacher, P., Werner, C., & Gerger, H. (2017). Trust in the health care professional and health outcome: A meta-analysis. *PLoS ONE*, *12*(2). https://doi.org/10.1371/journal.pone.0170988

Blendon, R. J., Benson, J. M., & Hero, J. O. (2014). Public trust in physicians—U.S. medicine in international perspective. *New England Journal of Medicine*, *371*(17), 1570–1572. https://doi.org/10.1056/NEJMp1407373

Cain, M., & Mittman, R. (2002). *Diffusion of innovation in health care* (p. 29). California Healthcare Foundation.

Center for Devices and Radiological Health. (2019, March 13). *Computer-assisted surgical systems*. U.S. Food and Drug Administration; FDA. https://www.fda.gov/medical-devices/surgery-devices/computer-assisted-surgical-systems

Center for Devices and Radiological Health, & Office of Surveillance and Biometrics. (2013). *Medical product safety network (MedSun) small sample survey – final report* (pp. 1–16) [Small Sample Survey]. U. S. Food and Drug Administration. https://www.fda.gov/media/87485/download

Coutrè, L. (2019, September 25). *Drilling into the future of robot-assisted dentistry*. Crain's Cleaveland Business. https://www.modernhealthcare.com/technology/drilling-future-robot-assisted-dentistry

Cui, L. (2016). *Categories of adopters*. Integrating IPad in Healthcare. https://sites.google.com/site/instructionaldesignknowledge/diffusion-of-innovation-theory/matrix

Davies, B. (2000). A review of robotics in surgery. *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine*, *214*(1), 129–140. https://doi.org/10.1243/0954411001535309

Diskin, N. (2020). *Analyzing Patient-Physician Trust Factors*. [4]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA

Evans, R. S. (2016). Electronic health records: Then, now, and in the future. *Yearbook of Medical Informatics*, *Suppl 1*, S48–S61. https://doi.org/10.15265/IYS-2016-s006

Graham, J. L., Shahani, L., Grimes, R. M., Hartman, C., & Giordano, T. P. (2015). The influence of trust in physicians and trust in the healthcare system on linkage, retention, and adherence to HIV care. *AIDS Patient Care and STDs*, *29*(12), 661–667. https://doi.org/10.1089/apc.2015.0156

Hurtado-de-Mendoza, A., Cabling, M. L., & Sheppard, V. B. (2015). Rethinking agency and medical adherence technology: Applying Actor Network Theory to the case study of digital pills. *Nursing Inquiry*, *22*(4), 326–335. https://doi.org/10.1111/nin.12101

Khanna, D. S. S., & Dhaimade, P. A. (2017). Artificial intelligence: Transforming dentistry today. *Indian Journal of Basic and Applied Medical Research*, *6*(3), 161–167.

Korb, W., Marmulla, R., Raczkowsky, J., Mühling, J., & Hassfeld, S. (2004). Robots in the operating theatre—Chances and challenges. *International Journal of Oral and Maxillofacial Surgery*, *33*(8), 721–732. https://doi.org/10.1016/j.ijom.2004.03.015

Kvalnes, Ø. (2017). *Fallibility at work*. Springer International Publishing. https://doi.org/10.1007/978-3-319-63318-3

Lanfranco, A. R., Castellanos, A. E., Desai, J. P., & Meyers, W. C. (2004). Robotic surgery. *Annals of Surgery*, *239*(1), 14–21. https://doi.org/10.1097/01.sla.0000103020.19595.7d

Milner, M. N., Anania, E. C., Candelaria-Oquendo, K., Rice, S., Winter, S. R., & Ragbir, N. K. (2020). Patient perceptions of new robotic technologies in clinical restorative dentistry. *Journal of Medical Systems*, *44*(2), 33. https://doi.org/10.1007/s10916-019-1488-x

Morris, B. (2005). Robotic surgery: Applications, limitations, and impact on surgical education. *Medscape General Medicine*, *7*(3), 72.

Neha, S., Shantipriya, P., Shekhar, K., Smitha, R., Ravichandra, C., & Sindhura, G. (2017). Micro robot—A revolution in endodontics. *Annals of International Medical and Dental Research*, *3*(4). https://doi.org/10.21276/aimdr.2017.3.4.DE2

Obadan, E. M., Ramoni, R. B., & Kalenderian, E. (2015). Lessons learnt from dental patient safety case reports. *Journal of the American Dental Association (1939)*, *146*(5), 17. https://doi.org/10.1016/j.adaj.2015.01.003

Obama, B. (2016). United states health care reform progress to date and next steps. *Jama*, *316*(5), 525–532. https://doi.org/10.1001/jama.2016.9797

Parmar, A. (2017, July 28). *Florida startup aims to make robot use in dental implants ubiquitous—MedCity News*. MedCity News. https://medcitynews.com/2017/07/florida-startup-aims-make-robot-use-dental-implants-ubiquitous/

Rabin, R. C. (2014, April 21). 15-minute visits take a toll on the doctor-patient relationship. *Kaiser Health News*. https://khn.org/news/15-minute-doctor-visits/

Rawtiya, M., Verma, K., Sethi, P., & Loomba, K. (2014). Application of robotics in dentistry. *Indian Journal of Dentistry*, *6*(4), 8.

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). *Diffusion of innovations*. Routledge. https://collab.its.virginia.edu/access/content/group/be8c0ab8-7a17-4f46-b11c-18f064232f0c/c0c25af1-f2b4-4a80-a8dd-2dc583d43d72/CDB_s%20Readings/Rogers-singhal-quinlan-june19-07-doi-word-file-stack-salwen_1_%20copy.pdf

Sarewitz, D., & Woodhouse, E. (2003). *Small is powerful*. Island Press. https://cspo.org/legacy/library/100915F0RQ_lib_SarewitzSmallIsP.pdf

Shetty, N. J., Swati, P., & David, K. (2013). Nanorobots: Future in dentistry. *The Saudi Dental Journal*, *25*(2), 49–52. https://doi.org/10.1016/j.sdentj.2012.12.002

Suttin, Z., & Porter, S. (2016). *Robotic device for dental surgery*. https://patentimages.storage.googleapis.com/eb/63/54/7522df7896e5b1/US20160354169A1.pdf

Sweeny, J. (2018, April 10). *The eroding trust between patients and physicians*. Medical Economics. https://www.medicaleconomics.com/view/eroding-trust-between-patients-and-physicians

Thom, D. H., Hall, M. A., & Pawlson, L. G. (2004). Measuring patients' trust in physicians when assessing quality of care. *Health Affairs*, *23*(4), 124–132. https://doi.org/10.1377/hlthaff.23.4.124

Zhang, X., Yu, P., Yan, J., & Ton A M Spil, I. (2015). Using diffusion of innovation theory to understand the factors impacting patient acceptance and use of consumer e-health innovations: A case study in a primary care clinic. *BMC Health Services Research*, *15*(1), 71. https://doi.org/10.1186/s12913-015-0726-2