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A characterization of professional media and its links to research

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Abstract

The publishing industry is a vast system whose elements form a metaphorical ecosystem with knowledge flowing through connections between heterogeneous elements. In this paper we seek a more robust understanding of different types of literature, and whether and how they support one another in the diffusion of knowledge. We analyze a corpus comprising professional electronic media in US dentistry and its relation to the peer reviewed journal literature. Our corpus includes full text from magazines, news sites and blogs that provide information to clinicians. We find links to research are made through several mechanisms: articles describing new clinical guidelines, referencing, summaries of recently published journal articles and crossover authoring. There is little to no apparent time lag in the diffusion of information from research literature to professional media.

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Introduction

General dentists provide regular care to most people on an annual basis (National Center for Health Statistics 2017), yet general dentistry is a little studied field. Like many professions, university dental research advances knowledge while a large profession practices in the community often not in daily contact with universities. In medical fields, to advance both the profession and scientific field, research needs to inform the clinic and the clinic needs to inform research. Advancing science and practice depends on the ability to effectively transfer credible knowledge between the research and practitioner communities, and examining their literatures can provide insight into this process.

The importance of this and related processes and the challenges they present have motivated research into evidence-based medicine, diffusion of innovation, societal impact of research, technology transfer and more. Scientometricians have engaged with parts of this wider landscape to develop alternative metrics of value for peer-reviewed papers. Many alternatives have been investigated for their correlation with the gold standard of citation counts, including counts of Mendeley uploads, Tweets, and mentions in: blogs (Bornmann 2015), newspapers (Begum, Pallari, and Lewison 2016), regulatory impact analyses (Desmarais & Hird 2014), policy documents (Bornmann, Haunschild & Marx 2016), clinical trials documents (Thelwall & Kousha 2016) a drug information database (Thelwall, Kousha & Abdoli 2017) and clinical practice guidelines (Grant et al. 2000; Kryl et al. 2012; Lewison & Sullivan 2008; Thelwall & Maflah 2016). Counts of references in these documents are interesting because they signify broader societal interest in research output.

Beyond counting references to attribute value to journal articles, it is possible to examine the role other literatures play in the research enterprise. Social scientists for example publish in four literatures – journals indexed in WoS, but also unindexed national language journals, books and enlightenment literature or periodicals aimed at a broad professional or educated audience. Each kind of literature has a role to play in advancing and disseminating scholarship to different audiences, but only one is present in the WoS indexed corpus (Hicks 2004; Lopez Piñeiro & Hicks 2015). The reporting of scientific results in newspapers and the effects of media coverage on research has been much studied (for example Rödder., Franzen, and Weingart 2011). The reverse relationship, that is referencing from academic journals to the *New York Times* has been growing strongly and serves a variety of purposes in advancing knowledge with some newspaper articles having been highly cited (Hicks & Wang 2013). The relationship between technology and science has been investigated through patent-to-paper citations (see for example, Narin et al. 1997; van Raan 2017).

Viewed from this perspective, peer-reviewed journals are part of a vast publishing enterprise, and better understanding of the role journals play in this broader context will shed light on mechanisms through which research achieves broader societal impact. This paper delineates the heterogeneous publishing channels in one technical field, US dentistry, and explores the mechanisms that link the channels and so facilitate knowledge flow between researchers and clinicians. While we know that academic journals and professional information sources convey information differently, and at varying levels of detail, there remain important questions about how the content contained in academic journals and other publications relate to one another. In particular, we are interested in a more robust understanding of different types of literature, and whether and how they support one another in the diffusion of knowledge. Our aim is to answer these questions:

- What types of channels discuss clinically relevant knowledge? This will broaden our perspective beyond the peer-reviewed journal literature and signal a diffusion role for the growing set of other resources
- What are their characteristics? This will delineate the role each type of publication plays in knowledge dissemination.
- How much does professional literature build on research literature and with what time lag? This has implications for knowledge dissemination and uptake.

Background - The literatures

The scientific literature is not a "natural kind", in other words, it is a constructed category that takes work to develop and maintain. This was evident in the early nineteenth century when scientific advances were published not only in standalone monographs and learned society journals that contained only scientific material, but also in heterogeneous periodicals such as commercial journals, pamphlets, magazines and newspapers. Over time the idea of a "scientific literature" was constituted, with literature indexes performing much of the work of demarcation by including only periodicals exclusively devoted to scientific material. This undertaking began with the construction of the *Catalogue of Scientific Papers* by the Royal Society of London in 1867 (Csiszar 2017). The Web of Science (WoS) continued this work by building an index of a highly select group of journals, in isolation from the rest of published material. Working within this database or with the data compiled from it, one was encouraged to believe one was dealing with all the scientific literature that mattered, an idea which in turn served to reify the concept of a "scientific literature". Though the original intent was to index the core of the scholarly literature, the WoS indexed corpus came to be seen as defining the scholarly and criticized in this light. In recent years, this demarcation has been successfully challenged by those arguing that scholarship exists outside the boundaries of WoS, especially in regional and non-English language social sciences and humanities journals. Demands for a broader definition of scholarship have been met by PubMed, Scopus, Google Scholar and the Emerging Sources Index of WoS itself. Nevertheless, a more broadly drawn boundary still reifies and isolates the peer-reviewed literature.

In parallel with the challenge to the narrow delineation of scholarship, the past several decades have seen the expansion of non-academic, technical literature for knowledge-based professions. Figure 1 provides an impressionistic timeline (the x-axis is not to scale) illustrating this growth in US dental literature extending back to 1924 when the peer-reviewed, *Journal of the American Dental Association* (JADA) was founded. In the 1960s, the Academy of General Dentistry founded the similarly targeted *General Dentistry*. The peer-reviewed, commercially published, professionally oriented *Compendium of Continuing Education in Dentistry* was established in 1980. All three periodicals are indexed in PubMed but only JADA is indexed in WoS. The advent of the internet in the mid-1990s prompted existing channels to launch digital versions and enabled entirely new types of information providers – for-profit publishers of magazines and news sites and professionals blogging (Hicks, Isett & Melkers 2017; Melkers et al 2017). In contrast to the scientific corpus, the resulting literature is diffuse, unorganized and uncatalogued. Here we examine this diffuse professional literature.

Figure 1 Impressionistic timeline of the expansion of professional dental literature

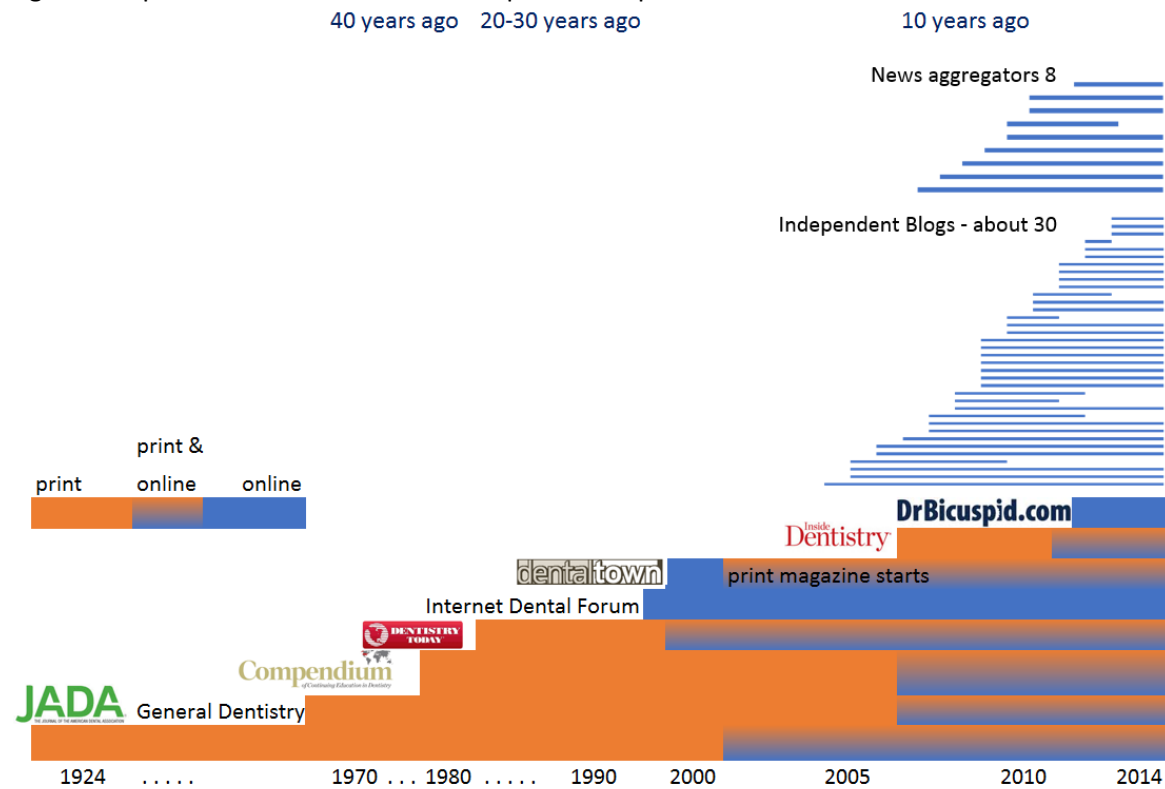


Table 1 – Peer-reviewed and professional literatures

	Journals	Magazines	News	Blogs
Publisher	Professional association	----- Commercial, for profit -----		Individuals
Article origin	----- Submissions -----	----- Staff writers -----		Single author
Quality control	----- Peer review -----	----- Editorial decisions about newsworthiness -----		None, vanity publishing
Audience	Academics	----- Practicing professionals -----		
Access	Subscription/ membership/ library	Ad supported, free registration on website		Open
Examples	J Oral & Maxillofacial Surgery Dentomaxillofacial Radiology JADA	Dentistry Today Inside Dentistry	Dr.Bicuspid.com Modern Dental Network	Endo Flucke Emmott

The operation of peer-reviewed journals is familiar to readers of this peer-reviewed journal article, but the operation of magazines, news sites and blogs may be less so. Table 1 compares these channels along five dimensions: publisher, audience, access, article origin and quality control as well as providing examples. The expansive dental technical literature is produced by three types of publishers – professional associations, who tend to own if no longer produce, peer-reviewed journals, specialized media companies producing dental magazines and news sites and practicing clinicians who blog. This characterization is stylized of course. Commercial publishers also own peer-reviewed journals,

associations also publish news magazines, and companies and associations also blog. Articles in each type of channel originate differently with journals accepting submissions from prospective authors and sending them out for peer review. Magazines also do this, though authors tend to be clinicians not associated with a university, whereas journal authors tend to have university affiliations. Magazines also employ staff and freelance writers to produce articles, publication of these is guided by editorial decisions about newsworthiness. Blogs are produced by a single author, or a small group of authors and focus on clinical or technical issues to varying degrees. The audience for journals is academics, though clinicians may also subscribe to journals in their specialty. Magazines and news sites are aimed at clinicians as are blogs. Peer-reviewed journals require a subscription, association membership or a library's subscription for access whereas magazines and news sites are supported by advertising and distributed free or require free registration on a website. Blogs are open access.

The channels differ not only in their publishing model but also in the type of information they convey. Table 2 illustrates these differences with sample article titles from a range of sources. The publications are ordered from most academic to least, i.e. specialist journals are followed by peer-reviewed journals in general dentistry then by magazines, news sites and blogs. The articles all concern a then innovative dental imaging technique CBCT or cone beam computed tomography (see below). Table 2 illustrates the differences between the literatures in their approach to this topic. The two specialist, peer-reviewed journals exhibit high technical complexity evidenced by their heavy use of jargon, in this case anatomical vocabulary, concern with technique – sialography - and with measurement. Using CBCT to obtain measurements of variable jaw geometry and ascertain ranges in the population is a prominent topic in the academic CBCT literature. The two general dentistry peer-reviewed journals, *General Dentistry* and *Journal of the American Dental Association* (JADA) use anatomical vocabulary overlapping more with general vocabulary – for example "teeth" - as well as exhibiting a concern with care – diagnosis, treatment and case management. *Compendium* and the next two magazines, *Inside Dentistry* and *Dentistry Today*, the latter of which is partially indexed in PubMed, deepen the concern with practice, explicitly taking the perspective of one who is a team manager as well as a clinician, and asking if the innovation is ready for application. The news sources, *Dr. Bicuspid* and *Modern Dental Network*, report on findings in the journal literature on measurement accuracy, note a non-clinical practice issue, liability, introduce brand names as well as a more informal style "your patients." The blogs continue this mix, with heterogeneity between blogs, some like Endo blog being more clinical and others like Flucke more commercially focused.

Table 2 suggests that peer-reviewed articles span a range from the most technically sophisticated and distant from patient care through concern with care and practice. Beyond the peer-reviewed literature, informality and concern with less technical sides of practice are visible. Important values such as technical sophistication, the credibility of peer review, grounding in the realities of clinical practice and being attuned to shifting pressures in dental care are accommodated to differing degrees in different channels. Blogs and news emphasize clinical realities as well as what is current, and though their reliability is not held in high regard, empirical analysis suggests their information may be as accurate as peer-reviewed literature where it overlaps (Hicks et al. 2018).

Professionally oriented blogs, news sites, magazines and journals differ in their publishing models and in their content. Publications source articles differently, value different types of information, and present it differently. Each channel disseminates information to practicing dentists about advances in knowledge, as well as information about the profession and management of a practice. In what follows, we explore the relationships between the channels, with a particular focus on research-based advances in knowledge and their reaching dentists through professional media.

Table 2 – Sample article titles

Publication	Sample Article Title
Journal of Oral and Maxillofacial Surgery	Cone Beam Computed Tomography and SimPlant Materialize Dental Software Versus Direct Measurement of the Width and Height of the Posterior Mandible: An Anatomic Study
Dentomaxillofacial Radiology	Cone beam CT sialography of Stafne bone cavity
General Dentistry	Cone beam computed tomography for diagnosis and treatment planning of supernumerary teeth.
Journal of the American Dental Association (JADA)	Cone-beam computed tomography and the orthosurgical management of impacted teeth.
Compendium	Cone-beam computed tomography in endodontics: are we there yet?
Inside Dentistry	Cone-Beam Computed Tomography: A Clinician's Perspective
Dentistry Today	Utilizing Digital Imaging to Enhance the Team Approach to Implant Treatment
Dr Bicuspid	Conebeam and multislice CT measurements found equally accurate
	Conebeam CT findings raise liability questions
Modern Dental Network	VIDEO REVIEW: Dr. John Flucke on Gendex Dental Imaging Solutions How to add multi-modality endodontics, the right CBCT 3D imaging system to benefit your practice and your patients
Endo blog	Uses of Cone Beam in Endodontics CBCT in Endodontics to Treat Difficult Anatomy, Preserve Teeth
Emmott blog	Accuracy of conebeam computed tomography Cone Beam Questions for Dale Miles
dentaltown	Cone Beam Imaging is Great, But What Am I Looking At? Filmed LIVE at Townie Meeting! By Dr. Dale Miles
Flucke blog	Thanks to Everyone Who Attended my Ultradent 3D Course Yesterday We've installed the Gendex CB500 ¹

Method

To probe the role of professional media in disseminating research results to clinicians, we compiled a database of professional electronic media in US dentistry. Electronic media were identified with the help of our project advisory group comprised of chairside dentists and hygienists, dental researchers, and dental professional association representatives. Media articles were collected by scraping all available articles from the websites of the following US based media: *Dentistry Today*, *Inside Dentistry*, *Dr. Bicuspid*, and *Modern Dental Network*. *Dentistry Today* and *Inside Dentistry* are the only two ad supported magazines distributed free to dentists that contain some peer-reviewed material but are not completely indexed in PubMed and not indexed in WoS. *Dr. Bicuspid* and *Modern Dental Network* are leading electronic news websites aimed at practicing dentists; access is free to those who set up an account. Data

¹ Not mentioned in this post, but admitted a few years later, the probably \$100,000 machine was a gift from the vendor and in return Flucke staffed the vendor's booths at professional conferences.

were gathered in 2016, resulting in a set of 15,789 articles published 2006-2016, with 2006 being the year the first channel established a website.

Blogs were inventoried through a combination of online Boolean internet searches (“dentist,” or “dental,” “hygienists”) and iterative searches of discovered sites, accompanying links, and existing curated lists of social media resources. This search process was conducted by a team of three researchers until the redundancy in sources led to saturation – that is no new sources were being identified. The blogs' contents were heterogeneous, with some aimed at patients, others discussing practice management and those of interest to us addressing clinically relevant information aimed at colleagues. To identify the relevant blogs, each was coded by three researchers to identify those of US origin, as well as for general content. Inconsistent codes were rechecked by two additional team researchers in order to resolve any differences and recoded accordingly. Content was coded as “patient oriented” if the communication was aimed to inform current and potential patients about the practice or clinical procedures; “clinically relevant” if treatment/clinical information relevant to dental clinicians was found; or “management/profession” if information was limited to financial, marketing, or management aspects of practice. We retained only US blogs containing clinically relevant information addressed to dental colleagues. Twenty-five blog websites were found containing 19,286 articles with the first dental blog post appearing in 2004. In total, 35,075 professional media and blog articles were scraped from the internet.

Our analysis includes both overall counts of the literature as well as more focused content analyses of part of the dental literature that discusses cone beam computed tomography (CBCT). CBCT is a 3-dimensional imaging technique in which the X-ray source rotates around the seated patient's head, obtaining hundreds of distinct images which are reconstructed into three dimensional voxels of anatomical data that can be manipulated and visualized with specialized software. The first CBCT scan was taken in 1994 and the first dental CBCT paper was published in 1998. In 2001 the FDA approved the first CBCT scanner for the US market. Use in US dentistry took off only in 2006-07 (Schulze 2015) marked by the first sessions on CBCT at the American Dental Association (ADA) national conference.

Results

Characterization of professional media

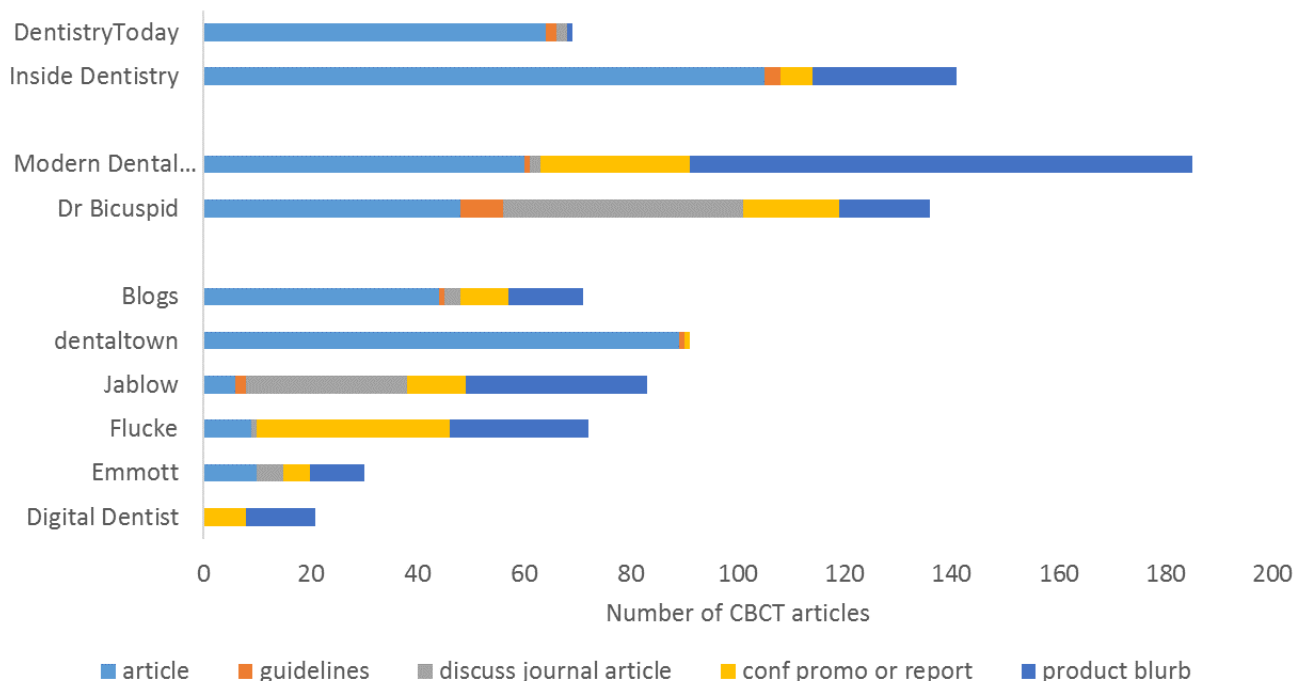
The first question in a comprehensive look at dental literature is how much does each type of publication contribute to the material produced for US dentists each year? We examine the number of articles published in 2015 because that is the most recent full year for which we collected data. In 2015, the two leading professional dental magazines, two dental news sites and 25 professional dental blogs published 6,800 articles for US dentists. As much as this is, there is more. Through their association memberships, US dentists have access to associations' peer reviewed journals. They also have free access to the peer reviewed *Compendium of Continuing Education in Dentistry*. Two surveys of information sources in US dentistry established that at least half of dentists read *JADA*, *General Dentistry* and *Compendium of Continuing Education in Dentistry* (Botello-Harbaum et al. 2013; Funkhouser et al. 2014). Medline reports that these three journals published 465 articles in 2015. Beyond this there is the full peer reviewed journal literature, which though it is not targeted at US dental clinicians is relevant to their work. Medline indexes over 8,400 additional English language journal articles worldwide published in 2015 under MESH major topic dentistry. Web of Science indexes about 8,200 articles published in 2015 in journals classified as Dentistry, Oral Surgery & Medicine, 1,942 of which list a US author. Thus, of the over 15,000 English language articles published in 2015 that are potentially relevant to US dentists ($\sim 8,200$ WoS/Medline + $\sim 6,800$ professional media), 45% are found in the leading professional media examined here.

Peer reviewed journals publish several different types of items: articles, letters and reviews. There is some variation across journals with letters being important in some and others focusing on reviews. From our perspective, it is also useful to delineate several different types of articles in the professional media, some analogous to articles in peer reviewed journals and others not. Unique to professional media is the product announcement. New or improved dental materials and equipment are introduced continuously and announced in press releases. Professional media undertake

to inform their readership of these developments, with some blogs posting the press releases. Professional channels also seek to inform readers of upcoming conferences and to report on highlights of recent conferences for those who could not attend. Product blurbs and conference coverage have no analogue in peer reviewed journals. The bulk of content in professional channels is articles. Like peer reviewed journals, *Dentistry Today* and *Inside Dentistry* publish peer reviewed articles with references. However, they also publish news articles written by staff or freelance writers. Of these, two types are particularly relevant for our discussion of links between research and practice – reports on new clinical guidelines and discussions of recently published peer-reviewed journal articles.

Figure 2 shows the number of CBCT articles by article type published by each magazine, news site and by blogs, with more prolific bloggers identified separately (Jablow, Flucke, Emmott) and others aggregated in blogs (independent) and dentaltown (blogs on the dentaltown platform). The profile of each publication is unique, with little similarity within publication types. For example, *Dentistry Today's* profile is more similar to that of blogs on the dentaltown platform than to the other magazine, *Inside Dentistry*. Though most material in the magazines are articles, *Inside Dentistry* also contains many product announcements. *Modern Dental Network* relies heavily on product and conference announcements as does high volume blogger Flucke, who generates 200-300 posts per year using this material. The other news site, *Dr. Bicuspid* publishes many articles discussing recently published journal articles.

Figure 2 – CBCT content heterogeneity across publications



A second method of examining the heterogeneity of articles in professional media is to examine authorship. Table 3 reports these counts for the full database. The convention in the dental journal literature is to list authors' degrees after their names. The magazines follow this convention. Therefore, Table 3 reports the number and share of articles in each channel that were authored by those with DDS or DMD degrees (dentists)², RDH or CDT qualifications (hygienists/technicians) and PhDs. Because of coauthorship, these figures cannot be added. Therefore, the total number of articles reporting authors with these qualifications is also given. "Authored other" reports the number of articles listing only authors with other qualifications, for example MBA or MD, or for whom no qualification is listed. These people may be freelance writers. Three of the four channels explicitly identify authors who are employed by the media company as staff writers or editors. Counts of these articles are given in line 6. Two channels identify articles

² Inside Dentistry sometimes prefaces a name with "Dr." rather than listing degrees. So the dentist count includes such articles.

sourced from company materials, such as press releases, and this count is reported in line 7. The final line tallies articles with no author. Although the numbers remain impressionistic because channels vary in their editorial conventions for identifying authors, Table 3 does make visible the difference between the magazines, with more than half their articles authored by clinicians and presumably peer reviewed, and news sites that rely on staff or freelance writers for the bulk of their material. Magazines of course also contain articles written by staff or freelance writers as well as material provided by industry and this differentiates them from peer reviewed journals.

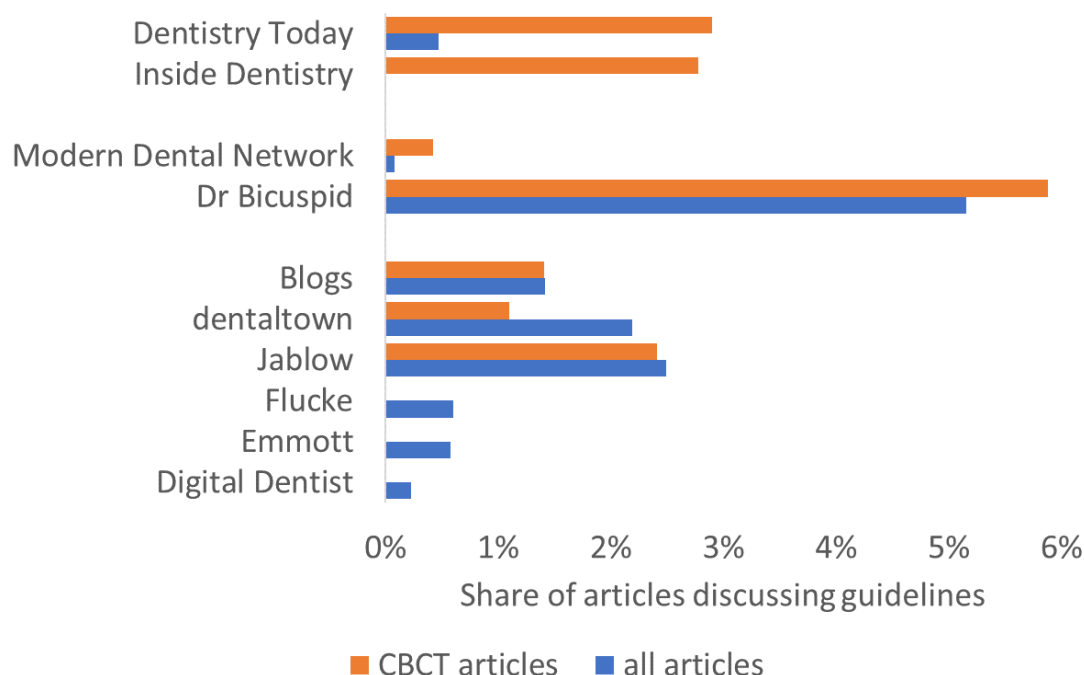
Table 3 Types of authors

	Magazines				News Websites			
	Dentistry Today		Inside Dentistry		Dr Bicuspid		Modern Dental Network	
Dentists	955	50%	1204	50%	173	3%	470	7%
Hygienists/technicians	88	5%	74	3%	19	0.40%	212	3%
PhD	91	5%	107	4%	13	1%	1	0%
Total with degrees	1043	55%	1250	52%	200	4%	679	11%
Authored other	122	6%	335	14%	1223	24%	2457	39%
Staff or editors	238	13%	--	--	3530	69%	167	3%
Company information	--	--	226	9%	--	--	431	7%
No author	497	26%	588	25%	167	3%	2632	41%
Total	1900	100%	2399	100%	5120	100%	6366	100%

Links between professional media and research

The role of professional literature in diffusing results of academic research to clinicians is crucial to achieving knowledge exchange between the clinic and research. What evidence do we see of academic research reaching the clinical audience and thus potentially achieving broader societal impacts if practice evolves in response? The category "guidelines" in Figure 2 accounts for few articles but appears broadly across almost all publications. Clinical practice guidelines aim to convey the results of research into practice. Figure 3 reports the share of CBCT articles and all articles that mention guidelines. Each CBCT article was inspected and classified, thus the data are of higher quality than the overall figures, which are based on the share of articles mentioning the word "guideline." The two sets of data are broadly aligned. The share of articles discussing guidelines ranges from less than 1% to 8%. That guideline reports are small in number, yet appear so broadly across most publications, suggests publishers feel new guidelines are highly newsworthy and relevant to their readership. Thus, professional literature performs an important service in broadly disseminating consensus, research-based guidelines tailored to influence practice.

Figure 3 – Share of articles discussing new clinical guidelines



A second indicator of the use of scholarship in practice is referencing from articles in the professional literature to academic journals, a deliberate link that has not been indexed or subject to analysis. As mentioned earlier, some material in *Dentistry Today* and *Inside Dentistry* is peer reviewed, and it is presumably these articles that contain references. 34% (640 out of 1900) of *Dentistry Today* and 42% (1005 out of 2399) of *Inside Dentistry* articles have reference lists containing, on average, 12 references. Articles in *Dentistry Today* are categorized, and the categories sometimes demarcate different types of articles³. For example, articles in the categories: Clinical Update, Management and Technique of the Week are written by staff writers and few have references. In contrast more than two thirds of the articles in the Endodontics and Implants categories have reference lists and the articles' authors have dental degrees. Thus, categories like Endodontics and Implants likely contain peer reviewed articles, often reporting work on particularly challenging cases. Although the articles do not fully follow journal conventions, for example not being divided into abstract, literature review, methods, and results, they often reference journal articles. Excluding articles in categories in which less than 10% of the articles have reference lists (i.e. Clinical Updates etc.), 65% of articles in *Dentistry Today* have reference lists.

A third link between professional and scholarly literatures is visible in Figure 2 as the one third of CBCT articles in *Dr. Bicuspid* and the Jablow blog that discuss journal articles. Dr. Bicuspid discussions of journal articles are written by staff writers, and often bring together several reviewed articles and interviews with the authors. The prolific blogger Jablow simply posts article titles and abstracts. Though not present in the CBCT case study, the full database reveals that *Dentistry Today*'s Clinical Update category reports on recently published papers and accounts for one-third of the articles in the magazine. This genre is also present in *Inside Dentistry* and the Dental Dude blog in which 60% of posts report the findings of journal articles with references to the source.⁴ Commenting on journal articles is part of a broader phenomenon with 2.3% of articles mentioning another of the other media examined here (*Dentistry Today*, *Inside Dentistry*, *Dr. Bicuspid*, *Modern Dental Network*, blogs). Professional media builds on other media, and channels are again heterogeneous in this.

³ Inside Dentistry's article categories are not as informative.

⁴ The other 40% of Dental Dude posts are practice updates.

A fourth mechanism by which professional media interacts with research is represented by people appearing in both the scholarly and professional literatures. There are several prominent authors with more than 100 papers indexed in Medline who have authored articles in the magazines and on news sites. The professors who also write for the professional literature can serve a valuable role in diffusing state of the art knowledge into practice. Their voice carries high credibility, which is why staff writers at these publications so often seek out professors to comment for articles. Channels differ in the extent of their interaction with professors. To find out how common is the quoting of academics in the professional literature, we searched for articles that contain the word "professor". We distinguished between mentions of professors in the text of the article, and articles authored by professors using the position in the text of the last instance of the word "professor". If "professor" was found at the end of the article, the article was counted as authored by a professor, otherwise it was counted as a mention. Table 4 reports the results. *Inside Dentistry* leads with almost half of articles involving professors in some way. *Dr. Bicuspid* and *Dentistry Today* follow with about half the reliance on professors as *Inside Dentistry*. *Modern Dental Network* and blogs (aside from Jablow's blog, discussed earlier) do not mention academics much at all.

Table 4 Share of articles authored by professors or mentioning professors

Media Type	Channel	Authored (%)	Mentioning (%)	Number of Articles
Magazines	Inside Dentistry	16	23	2,399
	Dentistry Today	9	4	1,900
News Websites	Dr. Bicuspid	<1	16	5,120
	Modern Dental Network		3	6,370
Blogs	(not Jablow)		1	16,238

Time lag

A perennial question in the use of research is whether there is a lag between research and application and if so, how long that lag is. Though we are unable to investigate use in practice, the existence of articles in professional magazines referencing the academic literature provides an opportunity to examine the speed at which knowledge diffuses to clinicians. To do this we view the academic literature as the source of research-based knowledge and *Dentistry Today* and *Inside Dentistry* are taken to reflect the state of knowledge of clinicians, since their authors largely do not have university affiliations. Comparing the average age of references in the magazines to the average age of references in the academic literature will tell us whether practice related articles draw on older academic knowledge than do research articles. References in both magazines are on average 6.93 years old.⁵ This is approximately equal to the average age of references in the medical literature in 2004 – about 6.75 years (Larivière et al. 2008, Fig. 3). Larivière and colleagues were interested in long-term change in the aging of scientific literature and the last year they examined was 2004. We see no increase over time in the average age of references in the magazines. We have 2004 data for *Dentistry Today*, an exact match to the last year of data in Larivière et al. At 6.67 this value is even closer to Larivière's et al.'s 6.75. Therefore, there is no evidence that practice-relevant knowledge lags behind scholarship in the speed with which it draws on the body of existing research.

Another way of looking at this question is to examine when discussion of new topics commences in each literature. Cone-beam computed tomography in dentistry required decades of development in mathematical theory beyond medical CT, which was launched in the 1970s. The first dental CBCT scan was taken in 1994 in Italy, and the first dental CBCT paper was published in 1998. This case does not represent an advance originating in dental research. Rather, CBCT in dentistry was an innovation introduced by manufacturers for adoption by both university researchers and clinicians in private practice. CBCT articles started appearing in scholarly journals in 2003 and in professional media

⁵ In this calculation, the year of publication was taken to be year 0, the year prior to publication as year 1 and so forth.

three years later, in 2006. This suggests that universities were three years ahead of the broader profession in turning their attention to the new CBCT technology. This may be because early on universities received donations of these upward of \$100,000 machines, whereas clinicians had to find the money to buy CBCT machines and so may have delayed purchases until clinical value was established. Thus, university faculty probably obtained access to CBCT machines earlier than clinicians and so could write papers about them earlier.

A contrasting picture is provided by the aforementioned commentaries on journal articles published in media and blogs. Commentaries discuss current journal articles, published in the same month or even advance access articles. That is, a selected, relatively small number of research results are discussed immediately, as news, in professional media and blogs. Presumably, articles that quote professors as sources are another vehicle for immediate transfer of frontier research knowledge to professional media.

The conclusion on time lags is mixed, with some mechanisms – referencing, commentaries, and people – suggesting no delay in research knowledge reaching professional media. The discussion of the innovative new topic of CBCT began three years later in media than it did in journal articles, suggesting a short delay. However, the advent of CBCT happened over a decade ago, before the full impact of electronic media. Today, electronic media has eliminated delays in information distribution and competition to be the first to report new developments has been enhanced by the entrance of new, electronic only, media channels. Therefore, delays most likely have been reduced or eliminated.

Discussion

We have found that magazines, news sites and blogs together publish a substantial amount of clinically oriented material for US dentists, at 45% of the combined total, professional media rival the global production of journal articles in dental journals. Balanced against this it must be noted that peer-reviewed journal articles are longer than the others and notionally do not duplicate material while each magazine, news outlet and blog could conceivably publish an article on the same development, for example the release of a new clinical guideline. That is, non-peer-reviewed media will contain duplicative articles.

Clearly, nobody reads everything. We can gain some insight into the reach of the different types of publication from circulation figures. Table 5 reports two measures of the estimated size of readership for two sample specialist journals, the most read general dentistry journals, the two dental magazines and a news service. The circulation figures in Table 5 come from media kits. All journals and magazines that carry advertisements have media kits on their websites. These pamphlets report audited circulation figures, among other information, because circulation helps determine the cost of an advertisement. A company called BPA Worldwide (www.bpaww.com) supplies the circulation data. BPA circulation figures and in one case web traffic data, are reported in the second column of Table 5. The second measure of readership is the percentage of dentists regularly reading the journal or magazine as reported in two surveys of dentists conducted in the late 2000s (Botello-Harbaum et al. 2013; Funkhouser et al. 2014). The third column contains the average of the findings from the two surveys. There are no figures for the share of dentists reading the two specialist journals or Dr Bicuspid because these were not included in the surveys. However, the surveys did include other specialist journals that were read by less than 10% of the surveyed dentists, which is consistent with the specialist journals' circulation figures in the second column.

Table 5 Circulation and share of dentists reading regularly

Media Type	Channel	Circulation	% reading
Specialist journals	Journal of Oral and Maxillofacial Surgery	2,810	NA
	Dentomaxillofacial Radiology	850	NA
General association journals	JADA	143,444	74%
	General Dentistry	33,000	46%
For profit, peer reviewed, free	Compendium	90,000	56%
Magazines	Inside Dentistry	132,000	20%
	Dentistry Today	130,000	46%
News website	Dr Bicuspid	57,000*	NA

* active members

The number of dentists in the United States is about 195,000 (Munson and Vujici 2016). Assuming, based on the content, as well as subscription arrangements, that the circulation figures count dentists, JADA reaches most of them, and most of them read it. The two magazines reach almost as many dentists, who pay somewhat less attention, with less than half reading the magazines. *Compendium*, *General Dentistry* and *Dr Bicuspid* reach a substantial fraction of the profession, with *Compendium* and *General Dentistry* read by about half. In contrast, specialist journals are read by a small fraction of the profession.

Clearly there is a limited audience for the highly technical information in peer-reviewed specialist journals. However, the association peer-reviewed journal model also characterizes the most broadly read publication in dentistry – JADA – which is aimed at the large audience of dentists who receive it as a benefit of their membership in their professional association and, survey data suggest, regularly read it. Magazines strive for the same audience, but survey data suggest that while they distribute widely, attention is not guaranteed. Peer-reviewed general journals, even those produced by commercial publishers, are read. And the relatively recently established news site also has a substantial following. Blog readership is unknown.

Broadly read media are ideal for disseminating material to practicing clinicians. Therefore, it was no surprise to find that all professional media published articles on new clinical practice guidelines. To develop guidelines, professional associations convene committees, whose members are often academics, to develop consensus statements of best treatment for designated conditions based on reviews of the research. The intent is to reduce variability in practice by providing a sound evidence basis for care. The committee consensus process and institutional backing serve to distinguish guidelines from reviews or meta-analyses and to garner the attention of clinicians. The aim is to influence clinical practice, and guidelines cite research. The clear research-to-practice intent of guidelines means that they are being analyzed to develop metrics of societal impact of research (Grant et al. 2000; Kryl et al. 2012; Lewison & Sullivan 2008; Thelwall & Maflah 2016). However, the extent to which guidelines actually influence practice is questioned. One perspective views flawed clinicians as the problem, resulting in a large literature exploring how to get clinicians to change practice. Another perspective questions the guidelines themselves, noting that committee members often have received money from drug makers, that guidelines assume patients have just one well defined condition and so are usually irrelevant to real patients, that guidelines have so proliferated that there can be hundreds of pages of guidelines relevant to a treatment decision, and that guideline development processes take so long that the guidelines are often out of date (Elwyn et al. 2016; Lenzer 2013).

If guidelines may be a less clear link between research and practice than originally intended, perhaps referencing provides a better signal because practicing clinicians author articles that reference journal articles, suggesting they are familiar with the referenced material. Doubts are possible however because most clinicians do not have access to most journal articles; magazine articles do not follow the conventional structure of journal articles and a substantial proportion of presumably peer reviewed magazine articles contain no references. Further work would be required to query authors of magazine articles to understand the influence of referenced work. Nevertheless, the extent of this

referencing contrasts with the limited referencing from academic journals to professional media. Over all years, the Web of Science records about 1,760 papers referencing *Dentistry Today* articles and 260 papers citing *Inside Dentistry* (as of February 2019). This is a miniscule percentage of the more than 150,000 dental papers indexed in the database. The largely one-way flow of influence represented by referencing from professional to journal literature accords with a strong version of the classic linear model in which basic research influences applied research, but the reverse is not true.

Perhaps the most substantive mechanism linking professional media with journal articles are commentaries on published journal articles in the magazines, news sites and blogs. This is a genre with a pedigree dating back to the earliest days of the scientific literature when many scholarly journals consisted of reviews and news of the literary and scientific world (Csiszar 2017, p. 30). At the time, this made it difficult to delineate the boundaries of the scientific literature and to ascribe authorship, since many considered commentaries more valuable than the original papers (Csiszar 2017, p. 38). This type of article helps provide access to research results to those who do not have access to scholarly journals nor the time to read them. Commentaries are reminiscent of popular press coverage of science. But although the relationship between the popular media and science has been examined closely (see for example Rödder, S., Franzen, M. and Weingart 2011), we are so used to the boundaries set by the Web of Science that the commentaries in professional magazines, websites and blogs and their role in engaging research with practice is invisible and goes unacknowledged.

The fourth mechanism of linkage is crossover authorship. The bulk of authors are either academics who write for peer reviewed journals or practicing clinicians who produce a paper or two for the magazines. However, there are several authors prominent in the peer reviewed literature who also write regularly for professional media. In each case, the author's work extends beyond their clinic and may benefit from the added visibility provided by a presence in professional media. One crossover author operates a continuing education company with a focus on testing new dental products (which offers CE credits on a Caribbean cruise). Another founded a firm offering consulting and seminars on practice management and marketing with over 40 employees; it is likely that his extensive presence in the professional literature is maintained by his marketing department in his name. A third consults for dental manufacturers and presents extensive continuing education programs. The crossover authors with a substantial presence in both literatures have interests broader than their academic or clinical jobs and writing in both literatures maintains the credibility and awareness of their expertise which they in turn sell through continuing education programs and consulting. The fourth crossover author does not fit this pattern. He was president of the American Academy of Oral and Maxillofacial Radiology at the time the promotion of CBCT imaging was criticized in the *New York Times* for minimizing radiation risk (Bogdanich & McGinty 2010). Much of his writing in professional media concerned radiation risk and seems to have constituted an outreach effort to the profession to manage the crisis sparked by the *New York Times* article. Crossover authors are capable of conveying current research to practitioners through their writing for professional media. The for-profit motivations of both the authors and the publications that devote resources to this type of publication indirectly suggest that readers are interested and therefore that this may be an effective mechanism of linkage.

Conclusions

The literature that discusses clinically relevant dental information is multiplex. There are of course the familiar scholarly journals indexed in Web of Science and more indexed in PubMed only. The newer electronic channels discuss the same topics, but in a less technical manner, more sensitive to the context of practice or more attuned to news values such as novelty, business relevance, and currency (Table 1). Non-indexed sources provide a substantial share of the available articles. Non-journal channels publish a mix of original articles, product introductions, conference promotions or reports, discussions of recent journal articles and articles discussing new clinical guidelines with the mix differing by channel (Figure 2).

The many and varied channels that are related in complex ways create the multiplex character of the literature that discusses clinically relevant information in dentistry and facilitates new research-based knowledge reaching clinicians who can update their practice in response. All channels contain articles about new guidelines signaling the attention paid to these efforts. The attention paid to the scholarly literature by clinicians is also signaled by referencing from magazine articles, largely written by clinicians without a university affiliation, to journal articles largely authored by university professors. Attention is also signaled by articles treating new journal papers as news and commenting on their implications. The effort to contextualize research knowledge for practice is also aided by researchers who write columns or other articles in magazines or interact with writers for magazines and news sites. None of these mechanisms involves a noticeable time lag.

Initial efforts to track the clinical impact of research have focused on references in guidelines. This relationship is substantive, but is just one among many in the metaphorical information ecosystem in which both researchers and clinicians participate. Exclusive focus on just one part of the system risks mistaking the part for the multiplex whole. Examining the information ecosystem as a whole provides a sense of the varied pathways knowledge can take to reach practice. It is of course a messier picture than that derived from examining the indexed literature alone, because part of the function of databases is demarcation in service of imposing order. However, constructing those boundaries has a cost in terms of our seeing and understanding the full picture of how knowledge is created and circulated between researchers and practicing professionals. Dentistry is similar to many professions - engineers, architects, accountants etc. - conducted in small practices in the community, largely separated from universities. Therefore, we expect that this study could be fruitfully replicated in other areas.

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