TECHNICAL NOTE

# PubMed alternatives to search MEDLINE: An environmental scan

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## ABSTRACT

The prime objective of this article is to introduce the newer methods to access, search and process MEDLINE citations. It also aims to provide a brief overview of each service's salient features. A targeted search was conducted in MEDLINE through the OVID gateway. This was followed with a search in Google Scholar as well as Google and Bing. Ninety-two web-based services that can be used to search MEDLINE were identified. The list was shortened to 24 by applying a set of relevancy criteria to select those services more relevant to general medical and dental users. Salient features of the selected services are outlined and a use case based classification of the system has been proposed to help dental practitioners and researchers select the appropriate service for a given purpose.

Received : 02-09-13
Review completed : 31-03-14
Accepted : 28-06-14

**Key words:** Algorithm, as topic, bibliographic, databases, information science, information storage and retrieval, Internet, Medical Subject headings, MEDLINE, National Library of Medicine (US), PubMed

The United States National Library of Medicine (NLM), a constituent of National Institute of Health in Bethesda, Maryland is regarded as a "center of information innovation since it's founding in 1836".[1] NLM has been indexing biomedical journals starting from 1879.[2] The index was published in print as Index Medicus until 1966 when it was converted to an electronic database and renamed MEDLINE. MEDLINE currently contains references to more than 23 million articles published in approximately 5,600 current biomedical journals.[2,3] Articles in MEDLINE are mapped to "Medical Subject Heading (MeSH)" terms corresponding to various concepts in biomedical sciences. MeSH is a controlled vocabulary system developed by NLM for the purpose of "indexing, cataloguing, and searching for biomedical and health-related information and documents."[4] MEDLINE contains more than 23 million citations and is expanding at the rate of almost million citations yearly. PubMed, (available at http://www.ncbi.nlm.nih.gov/pubmed) first released in January 1996 is the premier Internet gateway to the MEDLINE database. More than 2.2 billion searches were done through PubMed in 2012.[5]

To obtain best results, a PubMed search needs to be planned and developed. Searching PubMed using free text "Boolean" searches as in a general web search will not always produce desired results. The first and the most important step in developing a search strategy is to identify the key concepts in the information sought. For example, in a clinical question "What is the role of occlusion in temporo mandibular disorders?" Pain and temporo mandibular disorders are the two key concepts. Entering these key concepts one by one into the search box after selecting "MeSH" from the dropdown menu generates suggested MeSH terms. The appropriate term can be selected and a search performed to retrieve related articles. In addition to basic searches PubMed is capable of handling advanced queries-searches can be combined and filtered to locate most relevant articles.

Due to the ever-growing volume of biomedical literature, finding relevant search results from a PubMed search has become more and more challenging for its users. It is not easy for an average user to visualize the results in terms of relationship between MeSH terms in the results returned by a search query, volume, authorships, publication types and many other criteria. The very comprehensiveness and multifaceted nature of the database makes searching MEDLINE a daunting task for novice users.

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| Access this article online | |
|---|---|
| Quick Response Code: | Website: www.ijdr.in |
| | |
| | DOI: 10.4103/0970-9290.142562 |

NCBI has adopted a two pronged strategy to mitigate this problem: Improving PubMed's search functionalities (e.g, automatic suggestion of search terms); and allowing external entities-from either academia or industry to create alternative Web tools that are complementary to PubMed by making MEDLNE data and Entrez Programming Utilities (the Global Query Cross-Database Search System powering PubMed) freely available. Many of these new services offer considerable advantages and features over and above what is available via PubMed but are largely unknown outside of academia and niche users. The prime objective of this article is to introduce these newer methods to access, search and process MEDLINE citations to dental professionals and researchers. It also aims to provide a brief overview of each service's features and a guide based on use case scenarios for selecting the appropriate service for a given task. For the purpose of this article a PubMed alternative is defined as an interface other than PubMed to access MEDLINE.

## MATERIALS AND METHODS

The first step was to search peer reviewed literature and the worldwide web (www) to locate the available MEDLINE search services, other than PubMed. A targeted search was conducted in MEDLINE through the OVID (April 10, 2014) gateway. This was followed with a search in Google Scholar as well as Google and Bing-two of the most commonly used general search engines. Table 1 outlines OVID search strategy.

Google Scholar, Google and Bing was searched primarily using the following keywords combinations: "PubMed alternatives," "alternative MEDLINE interfaces." Search results from Google Scholar, Google and Bing were screened for relevance until the first five pages or point of no relevant return whichever was earlier. Reference lists of articles returned by the searches were also searched. Whenever an interface was found using web search or systematic search, its website was also searched for links to citations.

Citations were downloaded to Bookends, bibliography management software. After removal of duplicates the titles and abstracts were screened in duplicate in two rounds. In the first round of screening the title of abstracts of the articles were screened for reference to methods to search MEDLINE other than through the PubMed interface. In the second round of screening full texts of articles that passed the first round of screening were read and the name URL and short description of PubMed alternatives were extracted.The process is outline in Figure 1.

**Table 1: OVID MEDLINE search strategy**

| Search term/combination | Results |
|---|---|
| *MEDLINE/ | 1037 |
| *PubMed/ | 419 |
| alternative.mp. | 332448 |
| *Databases, Bibliographic/ | 1415 |
| *Search Engine/ | 314 |
| MEDLINE/ut [utilization] | 104 |
| PubMed/ut [utilization] | 28 |
| PubMed/td [trends] | 32 |
| MEDLINE/td [trends] | 39 |
| *Semantics/ | 9704 |
| # 1 AND #3 | 27 |
| # 2 AND #3 | 12 |
| # 7 AND #13 | 5 |
| #4 OR #5 OR #6 OR #7 OR #8 OR #9 | 1932 |
| Records downloaded (#11+#12+#13+#14) | 1976 |

To ensure that the results more relevant to dental professionals the following criteria were used to narrow the extracted list. To be included in the final result a web service needed to satisfy following criteria.

1. Designed to access the MEDLINE database as its primary resource
2. Web based
3. Freely accessible without registration or fee
4. Capable of conducting broad based searches, not focused on niche subjects (e.g, genetic research)
5. Not experimental or demonstration systems
6. Fully developed from the point of view of a user
7. Have a capability other than literature search to refine and filter initial search results
8. Not down for maintenance or other reasons in 3 repetitive searches between April 15 and 20, 2014.

## RESULTS

Ninety-three web-based services were identified by the search out of which 24 services presented in Table 2 satisfied all the criteria. The list of all identified services with the criteria applied may be available as an online extra or by request from the author. Table 2 lists the selected services in alphabetical order.

These new resources enhance MEDLINE search by means of innovative filters and visualizations. To make the results more comprehensible for the expert as well as nonexpert user alike, I classified the systems based on their expected application [Table 2, Figure 2]. Use case scenarios outlined by Lu has been adapted for this purpose.[6]

The individual web services are briefly described below in alphabetical order.

### Allie

A large number of abbreviations with different possible expansions are used in life science literature. This makes it difficult for a reader to understand scientific literature that is at the periphery or outside of their core expertise area. Allie uses ALICE (abbreviation LIfter using Corpus-based Extraction) to extract all types of abbreviations with their expansions from MEDLINE.[7,8]

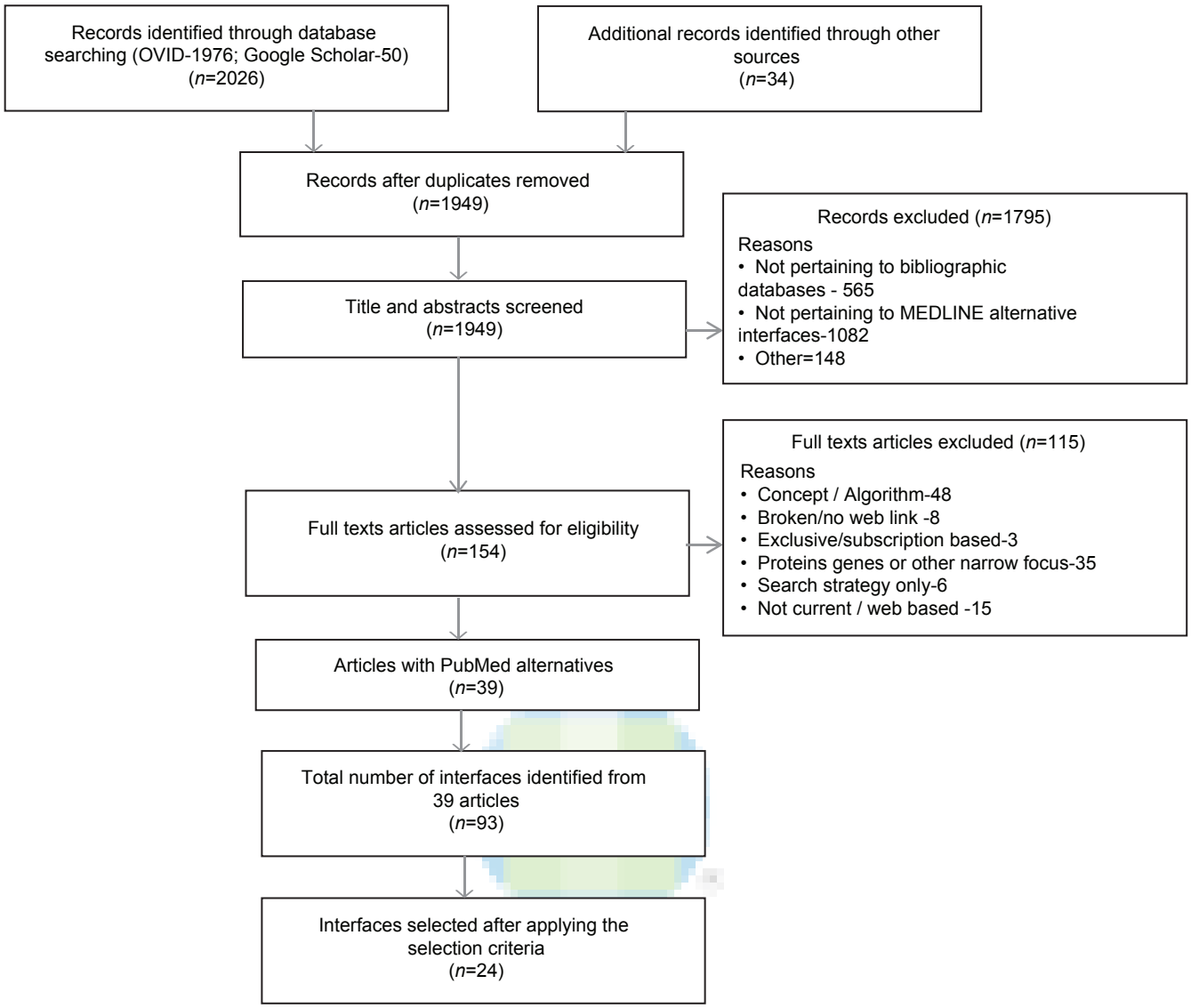


**Figure 1:** Study flow diagram

## Anne O'Tate

Anne O'Tate is an integrated, generic tool for summarization, drill-down and browsing of PubMed search results. Anne O'Tate displays multiple aspects of the articles to the user, according to predefined categories such as the "most important" words found in titles or abstracts; topics; journals; authors; publication years; and affiliations. Clicking on any given item opens a new window that displays all articles that contain the item thereby allowing the user to progressively drill-down the search without reframing the query as is required by PubMed.[9]

## Arrowsmith

Arrowsmith is a useful tool that helps in locating concepts that are common to two sets of articles. The first search defines "literature A" and the second search defines "literature C." The program then generates a "B-list" of words and phrases found in the titles of both literatures. Furthermore, Arrowsmith can generate an "AB list" (titles containing A and B or "BC list") (titles containing B and C) thereby allowing the user to explore a commonality or relationship between the two sets of articles.[10]

## askMEDLINE

askMEDLINE is targeted at the nonexpert PubMed user or even consumers in that it accepts queries in free text natural language.[11] For example entering a query such as "how to treat tooth pain" returns relevant articles from MEDLINE.

## BabelMeSH

BabelMeSH is a cross language tool to search MEDLINE/PubMed using medical terms or phrases in Arabic, Chinese, English, French, German, Italian, Japanese, Korean, Portuguese, Russian, and Spanish.[12,13]

**Table 2: List of selected PubMed alternative interfaces**

| Service name | Key feature | URL | Sponsor/developer |
|---|---|---|---|
| Allie | Allie searches for abbreviations and their corresponding long forms from titles and abstracts in the entire MEDLINE | http://allie.dbcls.jp | Database Center for Life Science, Japan |
| Ann o Tate | Integrated, generic tool for summarization, drill-down and browsing of PubMed search results | http://arrowsmith.psych.uic.edu/cgi-bin/arrowsmith_uic/AnneOTate.cgi | University of Illinois at Chicago |
| Arrowsmith | Finds concepts that may be present in common between two distinct sets of articles or to find information that is present in one field that may be relevant to another field of inquiry | http://arrowsmith.psych.uic.edu/cgi-bin/arrowsmith_uic/start.cgi | University of Illinois at Chicago and National Library of Medicine, USA |
| askMEDLINE | Free-text, natural language query for MEDLINE/PubMed | http://askmedline.nlm.nih.gov/ask/ask.php | National Library of Medicine, USA |
| BabelMeSH | Search MEDLINE using medical terms or phrases in Arabic, Chinese, English, French, German, Italian, Japanese, Korean, Portuguese, Russian and Spanish | http://babelmesh.nlm.nih.gov | National Library of Medicine, USA |
| BibliMed | Combines MEDLINE search with contextual links to contextual links to Wikipedia, Amazon, WorldCat, biomedical websites | http://www.biblimed.com/index.php?lang=en | Biblimed |
| BioText | Returns tables figures and captions in bioscience literature search | http://biosearch.berkeley.edu | University of California at Berkeley |
| DeJavu | A database of extremely similar MEDLINE citations | http://dejavu.vbi.vt.edu/dejavu/duplicate/ | Virginia Bioinformatics Institute |
| eTBLAST | A text comparison engine, eTBLAST finds the literature that best matches ALL the keywords in input paragraph of text | http://etest.vbi.vt.edu/etblast3/ | Virginia Bioinformatics Institute |
| GoPubMed | Knowledge-based search engine for biomedical texts based on GO and MeSH | http://gopubmed.org/ | Transinsight GmbH, Dresden, Germany |
| HubMed | Semantic MEDLINE search with relevence ranking, graphical display of related articles, linking of keywords to external sources of information and tagging | http://www.hubmed.org | Alf Eaton |
| iPubMed | Instant search. One of the fastest ways to search PubMed, allows fast and easy customization of the search too | http://ipubmed.ics.uci.edu | University of California at Irvine |
| KNALIJ | A visual exploration engine for MEDLINE | http://knalij.com | NA |
| Ligercat | Aggregates multiple articles in PubMed, combining the associated MeSH descriptors into a cloud, weighted by frequency | http://ligercat.ubio.org/articles | Biology of Aging project at the Marine Biological Laboratory Woods Hole Oceanographic Institution Library |
| MEDLINE trends | Automated yearly statistics for PubMed searches, useful mainly for bibliometric research | http://dan.corlan.net/medline-trend.html | Alexandru Dan Corlan |
| Medsum | Generate statistics on scientists, journals and topics | http://webtools.mf.uni-lj.si/public/medsum.html | Institute for Biostatistics and Medical Informatics University of Ljubljana, Slovenia |
| PICO | Searches MEDLINE in PICO format | http://pubmedhh.nlm.nih.gov/nlmd/pico/piconew.php | National Library of Medicine, USA |
| PMInstant | Fast, simple, instant search | http://pminstant.com | Jonathan Bouman |
| PubFocus | Statistical analysis of the MEDLINE/PubMed search queries enriched with the additional information gathered from journal rank database | http://pubfocus.com | University of Southern California |
| PubNet | Generates network graphs based on under defined characteristics, provides a visual way of comprehending the search result | http://pubnet.gersteinlab.org | Gerstein Lab, Yale University |
| PubReminer | Displays tables with number of results for characteristics (year, journal, author, word, MeSH term, country) and lets you combine results to build new queries | http://hgserver 2.amc.nl/cgi-bin/miner/miner2.cgi | Academic Medical Center, Amsterdam, Netherlands |
| Quertile | Semantic-based relationship driven search | http://www.quertle.info | Quertle, LLC, Nevada, USA |
| Refmed | Relevance Feedback Search Engine for PubMed | http://dm.postech.ac.kr/refmed/ | Pohang University of Science and Technology, S. Korea |
| SLIM | Slider interface for PubMed | https://pmi.nlm.nih.gov/slim/ | US National Library of Medicine |

PICO=Patient Intervention Comparison Outcome, GO=Gene ontology, MeSH=Medical Subject Headings, NA=Not applicable, SLIM: Slider interface for MEDLINE

## BibliMed

The unique feature of BibliMed is that it in addition to searching MEDLINE offers different contextual links from Wikipedia, Amazon, WorldCat and biomedical websites enabling the user to search the web and the MEDLINE from one integrated search.[14]

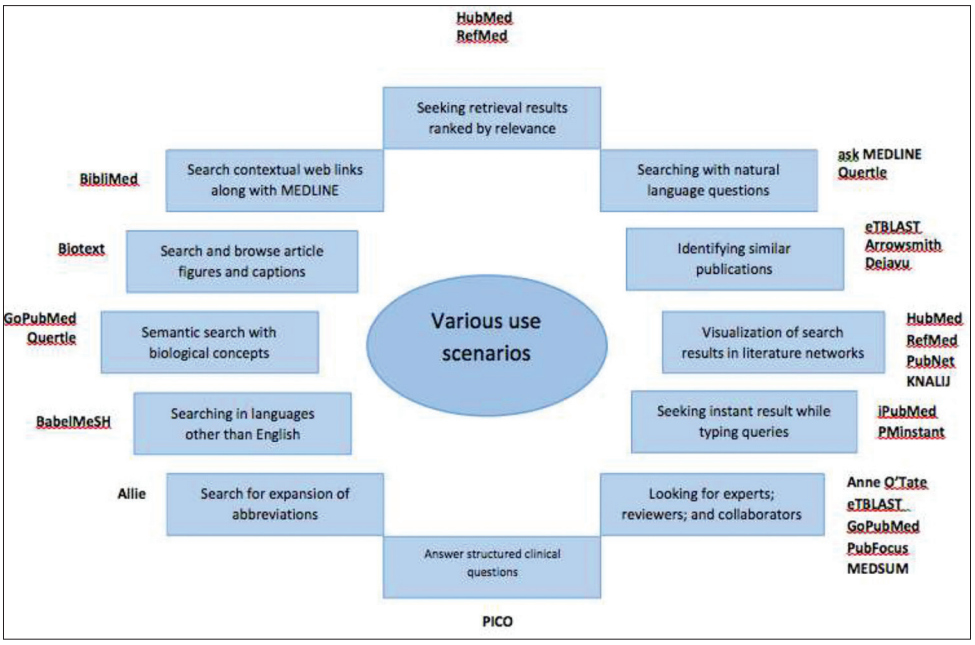


**Figure 2:** Use-case classification of PubMed alternatives

## BioText

BioText has the ability to search and browse article figures and their captions. The search engine returns a "grid view" that places multiple figures associated with the same keywords, providing new insight into the literature while the abstract/title search and list view shows at a glance many of the figures associated with each article.[15]

## eTBLAST, DeJavu

eTBLAST search engine uses a text similarity algorithm to accept natural language input and search MEDLINE for similar articles. The user can enter a sentence or paragraph from an article into the query field and search for abstracts with similar language.

The search can then be fine-tuned by giving more weight to particular words. eTBLAST also provides a similarity matrix of top documents, helps users find hidden trends in the literature collectively. It is also an effective tool to locate duplicate text and citations, find expert reviewers, appropriate journals and similar publications.[16] DeJavu is a publicly available database of highly similar Medline citations identified by eTBLAST.[17]

## GoPubMed

GoPubMed is a "knowledge based search engine for biomedical texts."[18] GoPubMed sorts the results of a MEDLINE query into four meaningful categories or "what," "who," "where" and "when" which can then be narrowed down to find the set of most relevant articles. The 'what' category presents the citations relevant to the query grouped into "top categories" based on the underlying concept, presented as a ranked list. The "who" category presents the main researchers and centers in the area.

The "where" category presents the location of persons, research centers, and universities engaged in research on the concept. This category also presents a ranked list of top journals publishing in query's domain. The "when" category presents the timeline of the search results. Each of these categories can be further refined to find out more specific results.

## HubMed

HubMed's key feature is its ability to enable the user to create and visualize clusters of related articles; the collections can be stored, grouped and tagged for easy retrieval later. In addition HubMed can "export citation data in multiple formats, receive daily updates of publications in their areas of interest, retrieve data from formatted bibliography lists, navigate citation links and store annotated metadata for articles of interest." HubMed also has a filter that compares all the words to Wikipedia database (and link the words to its Wikipedia page).[19]

## iPubMed, PMInstant

iPubMed and PMInstant provides instant feedback as the query is being typed. The results are updated with each keystroke. The search as you type paradigm allows the users to find results "on the fly" and enables them to dynamically modify or refine queries.[6,20]

## KNALIJ

KNALIJ is a visualization tool which searches PubMed and presents the results in the form of visual, interactive maps that can be zoomed, scaled, and explored according to new paths.[21]

### LigerCat

LigerCat aggregates multiple articles in MEDLINE, combining their MeSH descriptors and presenting them in a cloud, weighted by frequency thereby providing a visual overview of a set of PubMed articles. Important terms are returned as larger, while terms that are common across all of PubMed are down weighted proportionally.[22]

### MEDLINE Trends, MEDSUM

MEDLINE Trends returns annual and spatial (counts by country names) that conform to search strategy. Entering a few keywords describing a subject returns the history of the subject as to when the first articles about the subject appeared in MEDLINE indexed literature.[23] MEDSUM is a similar web service that generates statistics on scientists, journals with a live literature-summary interface, feeding directly off the current MEDLINE/PubMed database.[6]

### PICO

PICO is an often used acronym to denote a format for formulating research questions. The P notes the patient, problem, or population in a search, I is for the intervention of interest, C is for control and O is for outcome. PICO uses the same approach to develop PubMed queries by using a fill-in-the-blank menu format wherein the user is required to fill in the query in PICO format.[6]

### PubFocus

PubFocus automates analysis of MEDLINE/PubMed search queries by "enriching them with two widely used human factor-based bibliometric indicators of publication quality: Journal impact factor and volume of forward references." In addition, PubFocus also prioritizes citations and evaluates authors' impact on the field of search and analyses presence and occurrence of key biomedical terms within citations by utilizing controlled vocabularies.[24]

### PubNet

PubNet maps relationships returned by search queries converting them into network diagrams for graphical visualization, textual navigation, and topological analysis. PubNet can create complex networks derived from the contents of individual citations, such as genes, proteins, Protein Data Bank IDs, MeSH terms, and authors.[25]

### PubReminer

PubReminer processes queries based on free text and searches within the abstracts of the results of related MeSH terms to generate a frequency table that presents the results in terms of journals, authors, MeSH terms and text words. Selecting individual items from each column and combining them can further refine the search.[6]

### Quertile

Quertile is a "semantic driven, relationship-based" search engine for biomedical literature. It deciphers the relationship between search terms to find out the underlying concept and the most relevant literature. Quertile is capable of accepting natural language queries. Quertile searches for assertions made by the authors and therefore encourages researchers to input action words or verbs in the query to extract more focused results.[21]

### RefMed

RefMed allows the user to provide feedback on the initial results returned by a query by specifying whether each article is high relevant, somewhat relevant, or not relevant. The system accepts the feedback and then returns the top articles ranked according to the relevance function. The process may be repeated to improve the relevancy of the results.[26]

### Slider interface for MEDLINE

SLIM is a slider interface for MEDLINE searches. The user can refine the results returned by the original search query by publication date, journal subset, methodology filter and MeSH mapping with the easy to use sliders. This allows the user to instantly refine and refocus search strategies.[27]

## DISCUSSION

Our literature search was able to identify 93 such alternate interfaces to search MEDLINE. The list was pruned to twenty three by the application of a set of criteria filters designed with nonniche users in mind. Lu in 2011 had conducted a survey of alternate PubMed interfaces but his list didn't seek to differentiate between niche search services and general search services.[6] The present paper focuses on PubMed alternatives that may be useful for general researcher or healthcare professional.

Majority of the systems were developed on or after the year 2000, coinciding with the period of unprecedented advances in computing power, ubiquitous spread of internet and improvement in data mining technology. Most of the systems were developed by academic institutions with few exceptions like Quertile. The proliferation of alternate MEDLINE interfaces points to a trend toward "search-box simplicity" coupled with innovative ways to present results graphically and in meaningful categories. The deep literature mining and data processing capabilities of these newer systems facilitate literature based knowledge discovery wherein new knowledge is "mined" from a cluster of interconnected concepts as opposed to the conventional strategy of prospective goals oriented literature search.

PubMed presents search results in reverse chronological order which helps the searcher to view the most recent update but can be disadvantageous when the objective is to find the most relevant set of papers or concepts. A relevancy search engines like RefMed based machine learning and information retrieval (IR) techniques first retrieves search

results based on user queries and uses explicit user feedback on relevant documents to learn a ranking function by a so-called learning to rank algorithm RankSVM.[6] This iterative process can loop until the most relevant articles are located. This approach, although requiring more user involvement than the usual "search and locate" algorithm can be beneficial for researchers and clinicians as well.

Natural language search systems like PICO and askMEDLINE are ideal for a nonexpert user. They have been optimized for use from handheld devices also, making them a good reference tool for a busy clinician as well. Semantic search seeks to improve search accuracy by "understanding searcher intent and the contextual meaning of terms as they appear in the searchable data space, whether on the Web or within a closed system, to generate more relevant results."[24] Quertile, GoPubMed, HubMed and PubFocus are semantic search services that can find the contextual meanings and connections between concepts applicable to a query.

PMInstant and iPubMed belong to the new breed of PubMed search services that searches the database instantly, as the user types the query into the search box. This quickens the search process and also permits modulating the query in real time to find target literature. The user need not wait for the search results of the primary query to start refining the results.

Search outputs generated by MEDLINE/PubMed are not well classified and require lengthy manual citation analysis. Automation of citation analytics can be very useful and time saving for both novices and experts. Ligercat's primary strength is its ability to ease the search process by generating searchable tag clouds.

Due to proliferation of publication options and large volume of literature, finding an apt journal for publication is at times a challenge, especially for novice researchers. eTBLAST's text similarity is useful in those circumstances. Anne O'Tate also searches the text in an abstract and finds articles with similar text in PubMed. Text similarity based services are ideal for a researcher seeking to develop an overview of a topic or seeking collaborators and experts in the area.

Given the high volume of literature in PubMed, obtaining an overview of research activity within any particular biomedical field is an arduous task. PubReminer and HubMed analyses search queries by enriching them with journal impact factor and volume of forward references. In addition to providing basic volumetric statistics, PubFocus also prioritizes citations and evaluates authors' impact and locate top journals focusing on a given topic while PubReminer generates a set of hyperlinked frequency tables outlining the number of records published by year, journal, author, keyword, MeSH and country. This provides an interesting lens for focusing subsequent queries and optimizing results. Pubnet advances this further by returning a customizable network graph with nodes and edges connecting authors, coauthors, papers and MeSH terms. This can give information regarding the degree of MeSH term relation between papers or even the level of collaboration between two authors.

Although this paper has adopted a systematic search strategy to locate PubMed alternatives it is possible that the search might have failed to identify some of the systems; this must be especially true for those systems that have not yet been mentioned in peer reviewed literature or conference proceedings. Furthermore, sheer magnitude of the number of recent developments in the area has forced the narrative about each system to be brief and it is possible that some notable features of the systems might have been omitted.

The extreme heterogeneity of the web services there is need for future research to systematically test comparable services. Haynes *et al.* in 1994 tested 27 MEDLINE systems and found substantial differences in the performances of competing systems 13 of which were internet based.[28] Jacobs *et al.* developed a set of criteria to evaluate alternate MEDLINE systems and arrived at similar conclusions.[29] However, it must be noted that most of the systems tested by both Haynes *et al.* and Jacob *et al.* are not currently in service. Elizabeth Connor in 2010 conducted a descriptive comparison of the newer MEDLINE interfaces but it was limited to only 4: eTBLAST, SLIM, HubMed and ClusterMed.[30] Therefore there is a strong case to develop systematic criteria to evaluate the current systems. Other recommended avenues for future research is to test a selected subset of the interfaces identified in this article for dentistry specific searches, as well to develop a "package" of resources for the two broad categories of dental professionals-researchers and clinicians.

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**How to cite this article:** Keepanasseril A. PubMed alternatives to search MEDLINE: An environmental scan. Indian J Dent Res 2014;25:527-34.

**Source of Support:** Nil, **Conflict of Interest:** None declared.