Research in Prosthodontics: A 10-Year Observation of Trends in Topics, Collaboration, and Funding

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> **Purpose:** The objectives of this study were to investigate the nature of recently published prosthodontic literature, to investigate the types of collaboration and funding as well as their relationship, and to analyze the associations between collaboration and extramural funding. *Materials and Methods:* Three peer-reviewed prosthodontic journals were used for the analysis of articles published in 1998, 2003, and 2008. The articles were analyzed based on associations between the type of article, type of original research, collaboration, and funding. The chi-square test and logistic regression were used for data analysis (α = .05). **Results:** From 998 articles, a significant decrease in reviews (P < .001) and an increase in case reports (P = .001) were observed. Articles regarding dental materials ranged from 53% to 58% of the total original research, and the amount of collaboration among disciplines (P = .012), institutions (P < .001), and countries (P = .014) increased from 1998 to 2008. Most studies (77.5%) did not report funding, and articles related to dental materials had the most collaboration and funding. Dental materials (48%), clinical care (37%), and education/public health research (7%) were supported by private companies, and biomedical and translational studies were mostly supported by a university (13%) or the government (7%). A strong association was noted between collaboration (P = .010), extramural funding, and original research, especially related to education/public health (P < .001), clinical care (P = .013), and dental materials (P = .004). **Conclusion:** An increase in original research and collaboration was observed from 1998 to 2008. Studies that reported funding remained constant. A strong association with collaboration and funding was observed, along with studies involving clinical care, education, public health, and dental materials. Int J Prosthodont 2011;24:473-478.

Several authors have examined the research trends, such as types of articles and subjects of research, in their specialty.¹⁻⁴ An increase in the number of publications with a significant increase in collaborative efforts with other disciplines has been observed.^{2,5-8}

In prosthodontics, there has been a significant increase in the number of available publications,⁹ which may reflect the breadth of research activities occurring within the discipline and possible author collaboration with individuals in other disciplines.

Collaboration has been described as "crossfertilization of fields"¹⁰ or "boundary crossing,"¹¹⁻¹⁴ and it has played a significant role in new knowledge production because of friendlier problem-solving approaches.¹⁵ Some have expressed that through collaboration, scientists enhance the impact of their research by exploring literature beyond their traditional disciplinary boundaries,¹⁶ and these collaborative efforts are associated with creativity, progress, innovations, and many intellectual breakthroughs.¹⁷

Benefits also arise from collaborative efforts, since an increase in research activities and publications may warrant the need for more research funding. Obtaining grants and extramural funding has been considered a main factor for academic advancement

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and success,¹⁸ as well as advancement for the specialty itself. Several studies have reported that the increased number of funded research in medical fields^{19,20} was not necessarily linked to the increased amount of collaboration. In prosthodontic research, financial support can come from universities, the government, foundations, or private companies. The relationship between collaboration and source of funding in prosthodontics has not been investigated widely.

Given the complex nature of prosthodontics, from the interdisciplinary patient care to the wide use of dental materials, different forms of collaboration can be expected for research projects. Several researchers have described the trends in prosthodontic research and advocated the need for more collaboration.²¹⁻²³ However, research and collaboration in prosthodontics have not been well documented.

Using three prosthodontic journals and three publication years, the objectives of this study were to (1) investigate the nature of recently published prosthodontic literature; (2) investigate the types of collaboration, funding, and their relationship; and (3) analyze the associations between collaboration and extramural funding. The hypothesis was that the trends for collaborative efforts and extramural funding for original research would increase with time and that an increase in collaboration would correlate with increased extramural funding.

Materials and Methods

Three peer-reviewed prosthodontic journals were used for the analysis of articles published in 1998, 2003, and 2008. The journals were selected based on high circulation rate, the representation of prosthodontics and prosthodontic organizations, availability, and being written in the English language. The three journals selected for this study were: International Journal of Prosthodontics, Journal of Prosthetic Dentistry, and Journal of Prosthodontics. Abstracts, letters to the editor, editorials, and book reviews were excluded from the analysis. After gathering data from the first issue of 1998 of all three journals, three investigators were calibrated on the methods of data collection, categorization, and interpretation of the variables to ensure consistency. Calibration again occurred after gathering data from the rest of 1998 from all three journals. The investigators then were assigned to each journal, and the articles were assessed.

For each article, the following parameters were collected:

 Classification for published articles: The classification of the published articles was modified from a study by Kanavakis et al.² The published articles were classified using five descriptors: original research (articles that included measurements and analysis of data), review (not experimental), case report, technique, or other (not classifiable under the identified categories).

- Description of original research: After the studies were classified, only the original research was further examined. The categorization was modified based on the publication from Smollin and Nelson.²⁰ Six categories were used to identify the type of research: clinical care, dental materials, education/public health, biomedical science, translational science, or other (not classifiable under the identified categories).
- Collaboration: The number of institutions, disciplines, and the countries involved in the study were identified. Classification for collaboration was adapted from a study by Rosenzweig et al.⁵ Multi-institutional collaboration was defined as a study involving authors from two or more institutions, hospitals, military or research facilities, etc. Multidisciplinary collaboration was defined as a study involving authors from two or more specialties/disciplines. Multinational collaboration was defined as a study involving authors from two or more specialties/disciplines.
- Extramural funding: The sources of funding were identified for the original research. The classification for extramural funding was modified from a study by Birkhahn et al.¹ They were classified as private, university, government, no funding reported, or other (not classifiable under the identified categories). If the study reported more than one source of funding, it was classified as multiple.

Data were collected and entered into Microsoft Excel 2003 (Microsoft). Descriptive statistics including the frequencies and percentages of article types and topics in original research; frequencies and percentages of multidisciplinary, multi-institutional, and multinational studies; and the frequencies of funding and sources were calculated. Statistical software (SPSS version 17.0, SPSS) was used for more in-depth analyses. A significance level of .05 was used for all tests. Chi-square tests were performed to evaluate the difference from 1998 and 2008 in the types of published articles, types of original research, collaboration, and funding. Logistic regression models were constructed for multivariate analysis to assess the associations of types of original research with funding. A second logistic regression analysis was performed to evaluate the association between funding and collaboration within the original research studies.



Fig 1 Distribution of article types in 1998, 2003, and 2008. *P < .001, **P = .001.



Fig 3 Distribution of multi-institutional, multidisciplinary, and multinational collaborative efforts in prosthodontics in 1998, 2003, and 2008. *P < .001, **P = .012, ***P = .014.

Clinical care 📥 Dental material Biomedical Translational science science -Education/ Other 70 public health 60 50 40 % 30 20 10 0 1998 2003 2008

Fig 2 Distribution of type of original research in 1998, 2003, and 2008.



Fig 4 Distribution of funding type for original research in 1998, 2003, and 2008.

Results

A total of 998 articles were identified in the three representative years: 334 were published in 1998, 345 were published in 2003, and 319 were published in 2008. The change in the percentage of type of articles over the study period is shown in Fig 1. The decrease in reviews ($\chi^2 = 21.66$, df = 1, P < .001) and the increase in case reports ($\chi^2 = 10.17$, df = 1, P = .001) from 1998 to 2008 was statistically significant.

The distribution of the types of original research is shown in Fig 2. Original research related to dental materials ranged from 53% to 58%, and clinical care ranged from 27% to 30%. Education/public health, biomedical science, translational science, or other comprised 10% or less of the research types. The distribution of original research among all categories did not change significantly over time.

The amount of collaboration among different disciplines, institutions, and countries all increased over time, and the greatest increase was seen in collaboration between institutions (Fig 3). The increase in multidisciplinary ($\chi^2 = 6.38$, df = 1, P = .012), multiinstitutional ($\chi^2 = 39.10$, df = 1, P < .001), and multinational ($\chi^2 = 6.05$, df = 1, P = .014) collaboration from 1998 to 2008 was statistically significant.

Of 998 articles, 773 (77.5%) articles did not report any type of funding. The articles that reported extramural funding remained fairly consistent from 1998 to 2008 (Fig 4). No significant changes were observed.

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	Multi-institutional Multidisciplinary		Multinational
Dental materials	144 (57%)	174 (51%)	42 (51%)
Clinical care	68 (27%)	101 (29%)	27 (33%)
Education/public health	19 (8%)	27 (8%)	8 (10%)
Biomedical science	5 (2%)	17 (5%)	2 (2%)
Translational science	4 (2%)	8 (2%)	1 (1%)
Other	13 (5%)	17 (5%)	2 (2%)

 Table 1
 Distribution of Collaboration Based on Type of Original Research

Table 2Distribution of Source of Funding Based on Type of OriginalResearch

	Private	University	Government	Multifunded
Dental materials	40 (48%)	21 (68%)	31 (53%)	14 (39%)
Clinical care	31 (37%)	3 (10%)	13 (22%)	13 (36%)
Education/public health	6 (7%)	1 (3%)	5 (9%)	3 (8%)
Biomedical science	2 (2%)	4 (13%)	4 (7%)	3 (8%)
Translational science	0 (0%)	0 (0%)	4 (7%)	0 (0%)
Other	4 (5%)	2 (7%)	2 (3%)	3 (8%)

Table 3Logistic Regression Models for Indicators ofExtramural Funding for Type of Original Research andCollaboration

	Odds ratio (95% Cl)	Р
Type of original research		
Clinical care	3.1 (1.3–8.0)	.013*
Education/public health	3.4 (2.0–5.8)	< .001*
Dental materials	2.7 (1.4–5.5)	.004*
Biomedical science	0.9 (0.4–2.2)	.798
Translational science	0	.996
Other	0	.996
Type of collaboration		
Multidisciplinary	1.0 (0.8–1.3)	.825
Multi-institutional	1.6 (1.2–2.3)	.008*
Multinational	1.9 (1.2–3.2)	.010*

CI = confidence interval.

*P < .05.

The proportions of the collaboration and funded studies are described in Tables 1 and 2. Original research related to dental materials had the highest proportion of collaboration and funding in all categories. Dental materials, clinical care, and education/ public health research were mostly supported by private companies, whereas biomedical and translational studies were mostly supported by a university and the government, respectively. The relationship between extramural funding, collaborative efforts, and the type of original research is presented in Table 3. Within all types of original research, the logistic regression model showed a strong association with extramural funding when the type of article was related to education/public health, clinical care, and dental materials (odds ratio: 3.4, 95% confidence interval [CI]: 2.0 to 5.8; odds ratio: 3.1, 95% CI: 1.3 to 8.0; odds ratio: 2.7, 95% CI: 1.4 to 5.5, respectively). There was a strong association between collaboration and extramural funding for original research (odds ratio: 2.8, 95% CI: 2.0 to 4.2). Within the collaborative efforts, the logistic regression model showed a strong association with multinational and multi-institutional collaboration (odds ratio: 1.6, 95% CI: 1.2 to 3.2; odds ratio: 1.9, 95% Cl: 1.2 to 2.3, respectively).

Discussion

In this study, a significant increase in the collaboration between disciplines, institutions, and countries was observed that paralleled other research disciplines.^{2,6-8} Prosthodontic treatments are often complex and comprehensive; therefore, certain clinical trials may involve multiple disciplines. For example, clinical trials involving dental implants may use other surgical disciplines or multiple institutions. Some clinical trials have been criticized for poor design in the past,²⁴ and through collaborative efforts, studies could be designed and conducted with better approaches.

Many studies on dental materials involved collaboration. Traditionally, research on dental materials has analyzed physical properties or clinical performance.²⁵ Biocompatibility, biologic outcome, or host response have become a large part of dental materials research.^{25,26} This study found a wide range of collaboration with other disciplines, such as chemical engineering, oral biology, and microbiology. This study did not examine the specific subject of clinical care or dental materials, so it is difficult to determine the reason for the increased collaboration. However, data provided in this study do support the notion that more collaboration is occurring in prosthodontics with a variety of disciplines and locations.

Collaborative efforts in scientific research have been viewed both positively and negatively. Positive aspects of collaboration include new knowledge production,15 enhanced impact on research,16 and increased creativity, progress, and innovations.17 Collaborative works have been cited more frequently in scientific journals, suggesting that collaborations can produce higher quality research that has a higher impact.²⁷ On the other hand, collaborative research has been criticized as being a threat to the motivation of scientists and having adverse effects on the accountability of the research.²⁸ Other distinguished journals in different dental specialties may report extensive collaboration and funding; this study solely examined the prosthodontic specialty. Whether collaboration has a positive or negative impact, this study has shown an increase in the collaborative efforts. The scientific community can learn to embrace this trend and explore new areas while maximizing creativity and teamwork.

In the prosthodontic literature examined, studies related to dental materials encompassed the highest percentage of original research articles for all three years. In addition, "dental materials" was the topic that received the most amount of funding. The majority of dental materials and clinical study funding was from private companies. Private companies may develop relationships with institutions for testing of their products, so they may be willing to provide materials needed for studies as well as funding for some research projects.^{29,30} Similar to our findings, Moses et al¹⁹ showed that there has been tremendous growth in biomedical research, and the majority of the funding came from private companies. Even though private companies may invest in research and development with good intentions, there may be interest in commercial opportunity as well.³¹ Some studies have found a strong association between industry-funded studies and statistically significant positive results, which may suggest that certain funded studies can introduce bias that is favorable for the company.^{32,33} Critically assessing areas of greater need in research, developing programs, and using funds to improve those areas could potentially be beneficial for the growth and advancement of prosthodontics.

Articles related to public health, biomedical science, or translational science were fewer in number compared to dental materials or clinical care. A similar trend was observed in a review by Akagawa in 2006.23 According to the author, the proportion of articles written about topics such as biology, sociology, psychology, and epidemiology were small compared to dental materials when the International Journal of Prosthodontics and the Journal of Prosthetic Dentistry were analyzed from 2004 to 2005. It may be possible that few prosthodontists are involved in public health or biomedical or translational science compared to other areas or that they may publish their work in nonprosthodontic journals. Nevertheless, based on impact to the restorative component of prosthodontic practice, the selected journals were expected to have the greatest impact.

The overall incidence of extramural funding did not change significantly over time. Original research in the areas of clinical care, education and public health, and dental materials showed a strong association as predictors for extramural funding. However, the proportion of published articles in education and public health ranged from 6% to 10% of the total prosthodontic literature. Thus, this may not be a true representation of the association between extramural funding and studies in education and public health. The numbers of original research articles that were funded by the government represented 6% of all research. This was similar to a report by Lipton,³⁴ in which it was found that prosthodontics represented 9% of the NIH scientific award program in the past. A recent report from the NIH³⁵ showed examples of the collaborative efforts and distribution of funds. With a strong association between collaboration and extramural funding, data from this study can serve as encouragement for more prosthodontic researchers to collaborate.

Several limitations existed in this study that could affect the reported publication and collaboration results. Only three representative years within a 10-year span were examined. The trends described within this study were merely observations, based on three journals, and may not accurately represent all characteristics of the specialty. In addition, regarding source of funding, when no funding was reported, investigators assumed no extramural funding was involved in the study, which may not have been accurate. Another limitation was that the study included three journals only from the field of prosthodontics. As described by Nishimura et al,⁹ articles related to prosthodontics may appear in over 50 different dental journals. Many prosthodontic researchers may actively publish articles in different journals other than the three included in this study.

Conclusion

Three leading prosthodontic journals and their articles from 1998, 2003, and 2008 were examined for trends in research, collaboration, and extramural funding. While the topics in original research remained constant, a small increase in the number of original research publications was observed. Data showed a significant increase in the amount of collaboration among different institutions (P < .001), disciplines (P = .012), and countries (P = .014), while the number of funded studies remained fairly constant. Collaboration and research in the areas of clinical care (P = .013), education/public health (P < .001), and dental materials (P = .004) had strong associations with extramural funding.

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