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# A Longitudinal Evaluation of Collaboration in Plastic Surgery Clinical Research

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**Background:** Few dedicated, funded clinical research fellowship positions exist in plastic surgery. This study provides insights from an established clinical research fellowship, highlighting its educational impact and confirming the impact of positive institutional support and a collaborative-first approach.
**Methods:** All research fellows within the program from 2008 to 2020 were examined during their year of employment and subsequent 2 years. Internal and external collaboration trends were assessed using PubMed affiliations. Correlation between external collaborations and research impact were examined. Research impact was characterized by publication count, journal impact factor, and journal diversity.
**Results:** Thirty-one research fellows were identified, with a 100% match rate. Four phases of development were identified, and a three-period cycle of productivity was noted to occur every 3 years. A shift toward more external collaborations occurred after 2016 ($P = 0.008$). A positive correlation was observed between external collaborations and academic output (r = 0.72, $P = 0.004$), journal diversity (r = 0.74, $P = 0.004$), and journal impact (r = 0.63, $P < 0.05$). Significant growth was observed in the collaborative networks ($P = 0.002$), publications ($P = 0.003$), journal diversity ($P < 0.001$), and research personnel ($P = 0.002$).
**Conclusions:** As a result of our strategic decision to engage collaborators across multiple disciplines, there is discernible improvement in measurable impact, contributing to the growth of our program. Dedicating resources to foster deeper collaborations can enrich the field of plastic surgery research, recognizing that this investment fuels the cycle of productivity, offering promising returns to the future.
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## INTRODUCTION

Research remains a foundational component of academic plastic surgery and is crucial for advancement of the specialty.[1] Current literature has revealed that formalized research training in the field of plastic surgery is associated with future academic success, contributing to the progression of the field.[2,3] This academic success is accompanied by increased research output, career advancement, and acquisition of funding from the National Institutes of Health.[4–8]

In 2017, Carney et al[9] reported on the formation of a clinical research fellowship (CRF) program (est. 2008) in plastic surgery, consisting of one to two fully funded annual positions. Notably, the authors found increased departmental academic output and a 100% match rate in plastic surgery by the research fellows (RFs). In a 2013–2016 national survey study of 621 integrated plastic surgery applicants, applicants who had completed research fellowships matched successfully at a higher proportion than those who did not.[10] Romeo et al[11] reported benefits similar to those of a funded craniofacial CRF.

Few dedicated, formalized, and funded CRF positions available to senior medical students and surgical residents exist in plastic and reconstructive surgery. When options for clinical research programs are limited, those pursuing research years are left to seek informal research training with little to no support. This predicament is exacerbated with the evolving landscape in plastic surgery, namely

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the shift to pass/fail United States Medical Licensing Examination Step 1 scores and reduced independent positions.[12,13] These recent changes necessitate an examination of existing research programs and the factors that construct a productive program.

This longitudinal analysis provides insights from an established CRF, highlighting its educational impact, confirming the impact of positive institutional support and a collaborative-first approach. The specific aims were to (1) examine trends in academic productivity and research impact, while describing the infrastructure of the program, and (2) determine the role of expanding collaborations within the productivity of the program.

## Takeaways

**Question:** How does infrastructure of a clinical research fellowship and collaboration impact productivity?

**Findings:** We describe our infrastructure in four development phases with a repetitious cycle of productivity. Positive correlations existed between external collaborations and academic output, journal diversity, and impact. We illustrate the relationships between our department and other specialties over time using extensive collaborative network figures. Significant growth was seen in publications, journal diversity, and research personnel.

**Meaning:** Fostering deeper collaborations can enrich plastic surgery research, fueling the cycle of productivity and offering promising returns to the future.

## METHODS

A comprehensive program evaluation was conducted on all RFs from July 2008 to July 2020 within the CRF program at the University of Pennsylvania's division of plastic surgery. Research personnel were identified via the institution website and records kept by the institution's current research manager. To capture each researcher's full research impact, because manuscripts take time for acceptance and publication, the time window for examination included their active year of employment (1 year) and subsequent 2 years. Printed articles were chosen to remove the uncertainty of electronic prints and its published time.

Research impact was characterized by publication count, journal impact factor, and journal diversity.[14] Individual research productivity was evaluated by a thorough literature review by two independent researchers through PubMed, as determined by number of publications and number of journals. Extracted publications in print were manually categorized and sorted by year. To address projects that were passed on to the following clinical research year, thus causing an overlap in authorship, the higher authorship determined its respective year. For example, if an RF started a project during their year, but it was completed by the next RF who subsequently became first author, the project was credited to the second RF due to their higher authorship.

The average journal impact per year (active year +2 years) was calculated to measure the impact of the research program. Journal impact factor was chosen as a measurable variable of scholarly impact to assess the significance of a journal, providing dimensional information about the quality of the research published.[15] Journal impact factor was obtained by Journal Citation Reports,[16] whereas number of publications, number of journals, and journal impact factor were measured to offer insights on the growth of the program.

Internal and external collaborations trends were assessed using PubMed affiliations. To circumvent collaborations mistaken for an RF with their previous medical school affiliation, data on medical schools, graduate programs, and residency programs were collected for each RF. Internal collaborations were defined as any interdepartmental research conducted within the field of plastic reconstructive surgery in children and adults. For example, although the University of Pennsylvania and the Children's Hospital of Philadelphia are two separate institutions, both divisions of plastic surgery function as one unit; therefore, they are classified as an internal collaboration rather than an external collaboration. External collaborations were defined as (1) any collaboration with specialties beyond the plastic surgery department and (2) any collaboration with an outside institution, regardless of specialty.

Trend analysis using a linear regression model was performed for number of personnel, publications and journals, and average journal impact factor. Correlations between external collaborations and research impact were examined using Pearson correlation coefficients. Network figures of the institution's collaborations with specialties outside plastic surgery were generated. All statistical significance was set at a $P$ value less than 0.05. Data analysis was done in Microsoft Excel 365 (Microsoft Corp., Redmond, Wash.) and RStudio (version 4.3.1, Open Source International).[17]

## RESULTS

A total of 38 fully funded and seven unpaid or partially funded researchers were identified from 2020 to 2024. A majority of this cohort were men (78%). Excluding those who have nontraditional career paths or are current applicants, we report a 100% match rate (48.9% integrated, 24.4% independent, 2.2% other specialty). See Table 1 for demographic characteristics, match outcome, and type of funding. Of the 45 RFs, 31 RFs were included in this 2008–2020 study. During this period of examination, 364 peer-reviewed printed articles were published among 80 different peer-reviewed journals. See Figure 1 for journal distribution.

Overall, significant growth was observed in the collaborative networks ($P = 0.002$), publications ($R^2 = 0.85$, $P = 0.003$), journal diversity ($R^2 = 0.75$, $P < 0.001$), and research personnel ($R^2 = 0.73$, $P = 0.002$). We present a visual depiction of the initial phases of the program and its progression toward a more established and mature phase, represented by a color gradient. Figure 2 highlights the key developmental phases that allow for the cyclical productivity that is responsible for generating greater academic output. Starting from the second phase, we define here a 3-year cycle of productivity, with the first year denoted as the recovery period (R), the second year as the acquisition

**Table 1. Demographic Characteristics of Unpaid, Partially Funded, and Fully Funded Research Fellows**

| | Unpaid/ Partially Funded N = 7 | Fully Funded N = 38 | Total N = 45 |
|---|---|---|---|
| Sex, n(%) | | | |
| Male | 6 (85.7) | 29 (76.3) | 35 (77.8) |
| Female | 1 (14.3) | 9 (23.7) | 10 (22.2) |
| Match outcomes, n(%) | | | |
| Integrated plastic surgery | 4 (57.1) | 18 (47.4)* | 22 (48.9) |
| Independent plastic surgery | 1 (14.3) | 10 (26.3) | 11 (24.4) |
| Other specialty | 0 | 1 (2.6) | 1 (2.2) |
| Nontraditional career paths | 2 (28.6)† | 2 (5.3)† | 4 (8.9) |
| Current applicants | 0 | 7 (18.4)† | 7 (15.6) |
| Types of funding, n(%) | | | |
| Center of human appearance grant | 0 | 28 (73.7) | 28 (62.2) |
| Herndon B. Lehr endowment | 0 | 6 (15.8) | 6 (13.3) |
| Harrison scholarship | 0 | 2 (5.3)† | 2 (4.4) |
| R01 | 1 (14.3) | 1 (2.6) | 2 (4.4) |
| PSF/internal grant | 0 | 1 (2.6) | 1 (2.2) |
| None | 6 | 0 | 6 (13.3) |

*One research fellow completed a preliminary year before matching.
†Research fellows who completed 2 years of research, counted twice.

period (A), and the third year as the production period (P).

The linear regression model revealed an increase in external collaborations over time ($R^2 = 0.61$, $P = 0.008$), with a notable descriptive shift occurring in 2016—as reflected by the changes in leadership (Fig. 2). A positive correlation was observed between external collaborations and academic output ($r = 0.72$, $P < 0.001$), journal diversity ($r = 0.74$, $P < 0.001$), and journal impact ($r = 0.49$, $P < 0.05$). Collaborative increases were made possible with the expansion of research personnel. In 2014, a second position was added to the initial annual single position, which was expanded further in 2017 with an additional two to four RFs funded by new grants (Fig. 3).

We also analyzed collaborative sustainability, indicated by the persistent temporal relationships between plastic surgery and other specialties. Recurring collaborations with plastic surgery occurring more than four times ensued with the following specialties: orthopedics, gastroenterology, general surgery, obstetrics and gynecology, oncologic surgery, cardiothoracic surgery, and radiology (Fig. 4).

Although this illustration reveals sustained long-term relationships over time, we also provide here a separate network analysis (Fig. 5) for four snapshots in time to depict the strength of the relationship between plastic surgery and other specialties. These snapshots correlate with the end of each productivity cycle (and their 2 years of follow-up): 2010–2013, 2013–2016, 2016–2019, and 2019–2022. Our plastic surgery department seemed to have developed strong relationships with general surgery, orthopedics, medicine, and bioengineering for 2016 RFs and orthopedics, dermatology, and radiology for 2019 RFs.

## DISCUSSION

Formal research training programs with a commitment to instilling the highest standards of research are vital in the process of creating self-sufficient plastic surgery researchers.[18] Integrating high-quality clinical

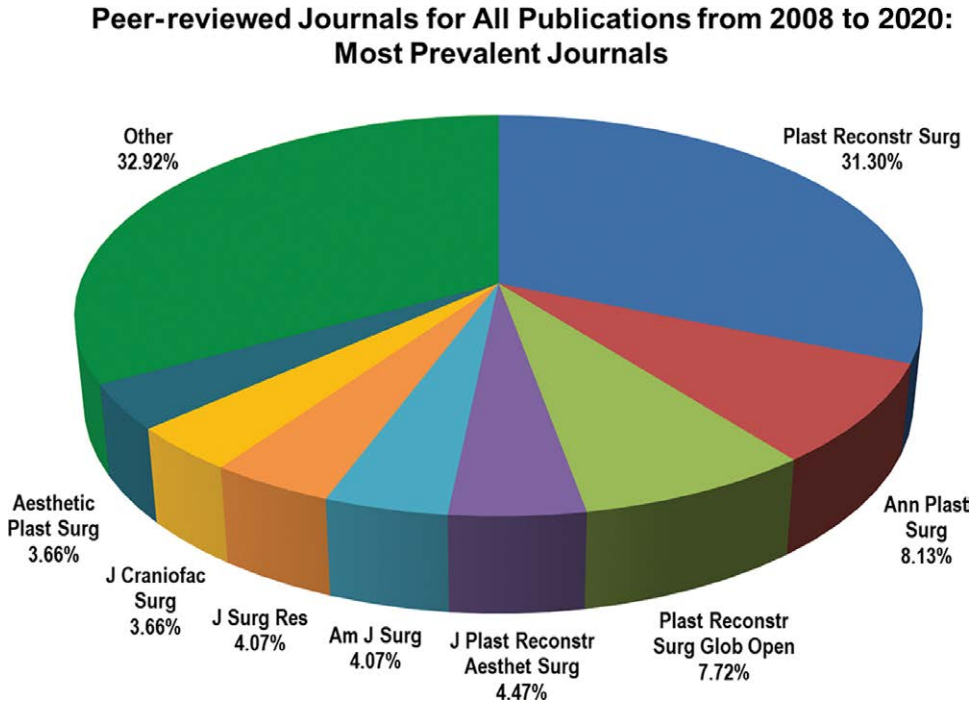


**Fig. 1.** A pie chart of peer-reviewed journals for all publications from 2008 to 2020.

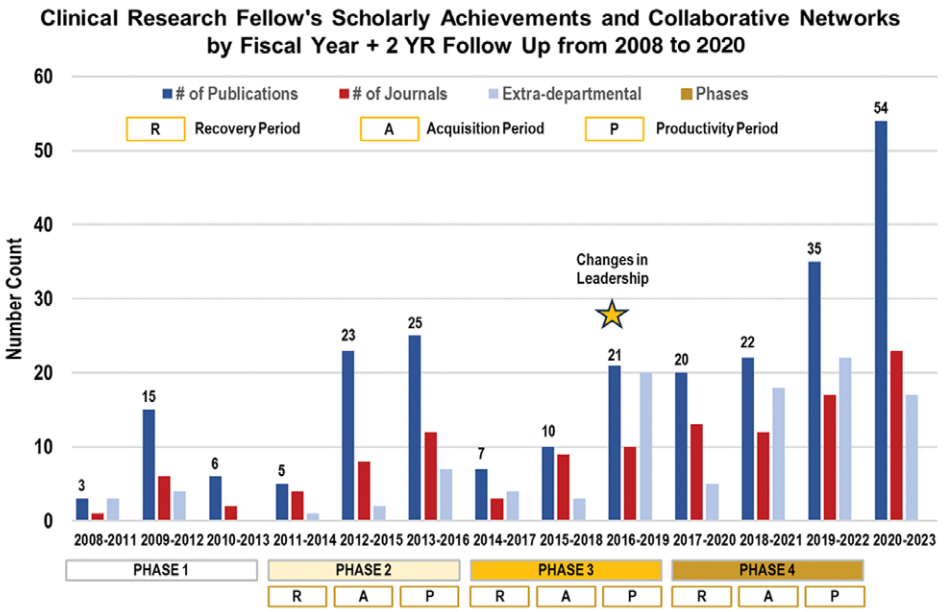


**Fig. 2.** A graph of all clinical research fellow's scholarly achievements and collaborative networks by fiscal year +2-year follow-up from 2008 to 2020. Includes the four phases of development, the three-period productivity cycle, and the impact of institutional support.

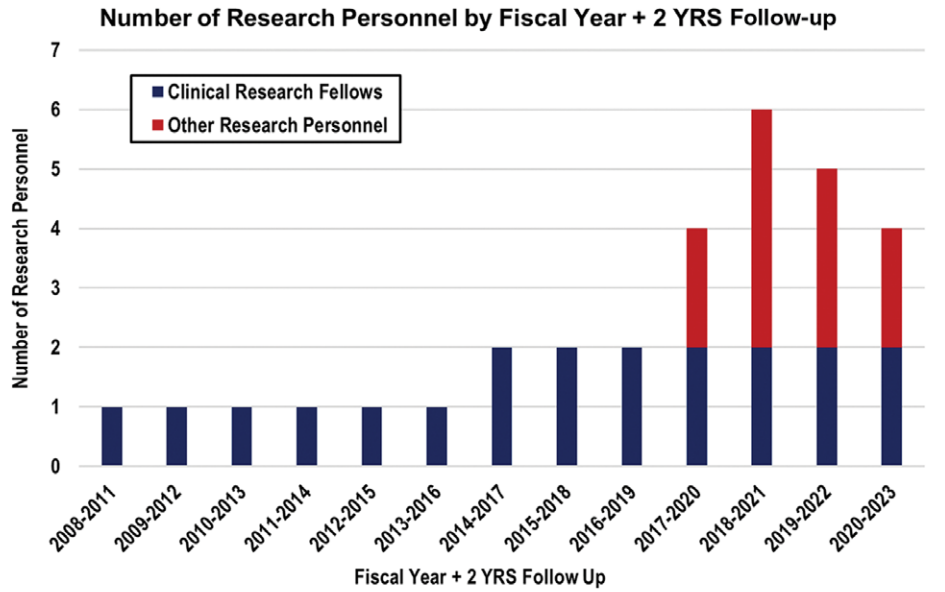


**Fig. 3.** A graph of the number of research personnel by fiscal year +2-year follow-up from 2008 to 2020.

research and collaborative skills into clinical practice is uniquely cultivated by the experience learned from a productive, funded CRF program. The data in this study shed light on the factors involved in the evolution of the program, its cumulative impact, and the role of a collaborative-first approach. Herein, we share our insights as to the critical components of a CRF program, from its pre-inception phases to long-lasting implications.

**Program Planning**

Before diving into the developmental phases, it is crucial to conduct a comprehensive needs assessment to identify knowledge gaps. This will guide the establishment of core values, vision, and mission statement. Next, we stress the importance of determining deliverables to create a robust evaluation plan. For example, we identified two knowledge gaps: (1) areas of unmet patient needs in plastic surgery and (2) lack of educational research

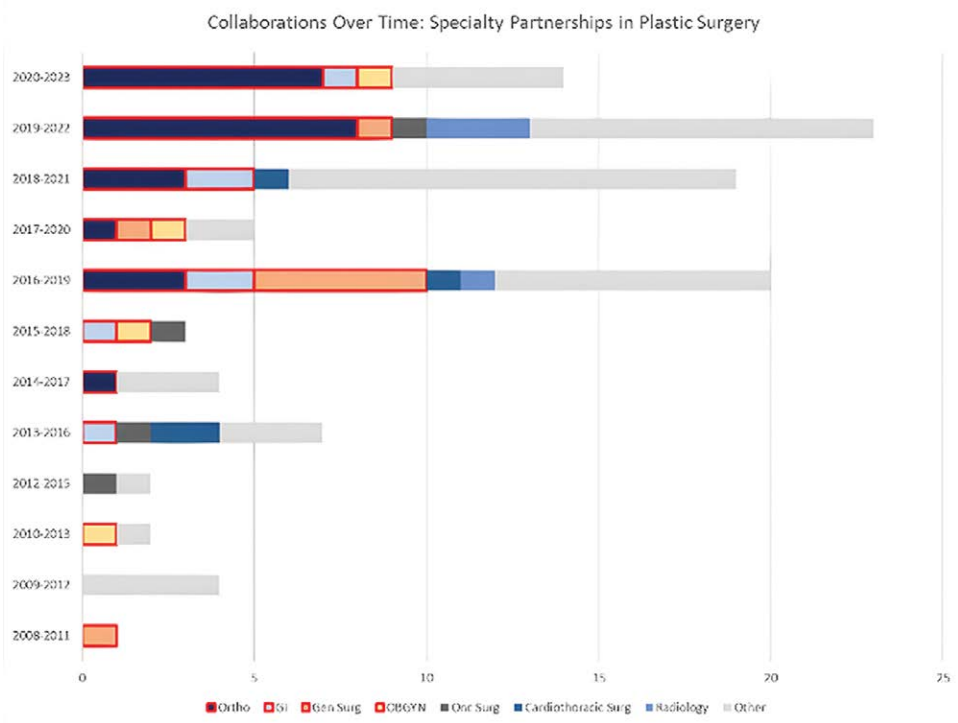


**Fig. 4.** A graph quantifying the long-standing specialty partnerships in plastic surgery, highlighting the sustainability of the program's collaborative efforts.

opportunities. The CRF aimed to provide RFs with critical and scientific thinking skills, which is useful in more-thoroughly understanding the field with implications to assess and address unmet patient needs. Example quantifiable deliverables of the program that can be evaluated include research outcomes such as publications, presentations at conferences, and journal impact.

**Establishment Phase**

The focus of the first phase should be answering the question, "How can we make this program more sustainable?" As seen in our data, the sustainability and longevity of a program is supported by involving strategic partnerships, securing buy-in from key stakeholders, stabilizing funding sources, and piloting the program to prove its viability. Examples of key stakeholders include medical students, residents, attendings, faculty, and collaborators. In this case, the CRF pilot program was developed by a dedicated team consisting of a research program director, departmental head, and a senior medical student researcher. Our program was initially funded through the Doris Duke Clinical Research Fellowship Program[19] and the Center for Human Appearance.[10] Continuous efforts were made to secure funding in all phases of the program, requiring rigorous work and time to complete the competitive process of acquirement.

**Emerging Productivity Phase**

The second phase is a pivotal phase where practical solutions are made to address the challenges of the pilot program, marking the beginning of the program's upward trajectory. The goal of this phase is to answer, "How can we set up future RFs for success?" This phase is characterized by developing a systematic approach to address logistical, legal, and ethical considerations, risk management, data privacy laws, research guidelines, and institutional regulations. Without these factors, resources may be underutilized or improperly allocated, which can have deleterious effects on both research productivity and the longevity of the CRF.

**Growth Phase**

At this point, we had developed an environment that fosters independent learning supplemented by valuable expertise from experienced senior researchers. The third phase began with the gradual expansion of personnel to meet the rising demands of the program. Initially, a research coordinator was appointed to ensure regulatory and university policy compliance. In 2014, a second RF was added, further expanding in 2017 with the incorporation of two to four research personnel to the research team. In 2016, the research coordinator was replaced with a research manager (PhD) to streamline training and workflow, monitor progress, and develop feedback systems. Our infrastructure was best described in a previous study conducted by Carney et al. This phase is characterized by the development of critical infrastructure, such as implementing and building on multiple databases, and standardized training of research personnel.

When selecting RFs, we take a holistic approach through the evaluation of a personal statement, curriculum vitae, two letters of recommendation, and multiple

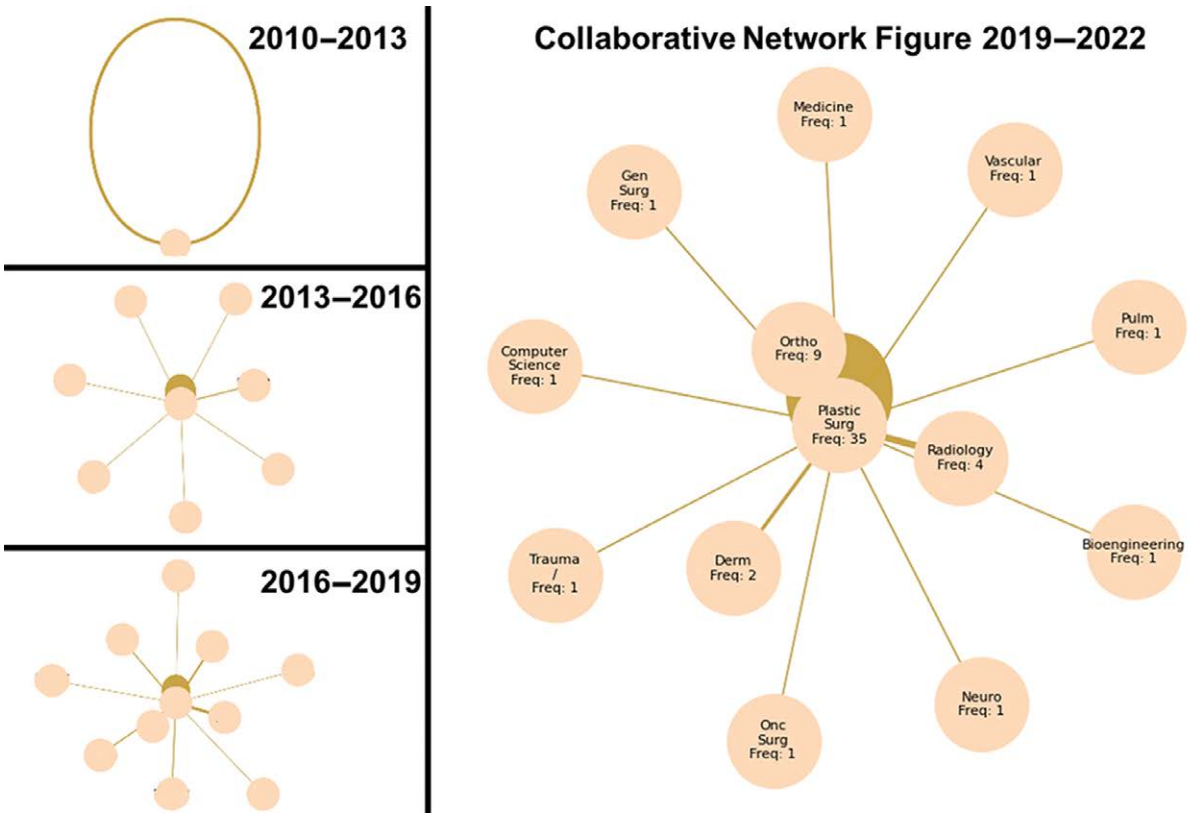


**Fig. 5.** Collaborative network figures for fiscal year +2-years follow-up at 2010, 2013, 2016, and 2019. With plastic surgery as a reference node, the lines connecting the nodes symbolize its relationship to another specialty collaboration. The thickness of each line indicates the strength of the relationship to the other specialties, and the distance between the nodes further illustrates the frequency and strength of these connections. Strong relationships with general surgery, orthopedics, medicine, and bioengineering could be seen for 2016 clinical research fellows and orthopedics, dermatology, and radiology for 2019 clinical research fellows.

interviews with the research team. Despite our high match rate into plastic surgery, we primarily focus on research potential when selecting candidates rather than their potential surgical skills. The strategic decision to expand personnel had a profound impact on the growth of a productive program. This decision provided the support needed to establish new partnerships and increase external collaborative efforts. The growth seen in journal diversity reveals the broadened reach in audience or fields, and the increase in journal impact factor suggests its greater influence and visibility.

We hope to revisit the literature on extensively examined factors that contribute to a successful research program. Similar to our findings, Rohrich et al[20] at UT Southwestern Medical Center articulated the key components contributing to a successful research program in their residency program, insights that hold relevance for the aforementioned CRF. These factors encompass vital elements such as financial support, administrative support, mentorship, a capable support team, research personnel, ongoing educational opportunities, an effective evaluation system, proficiency in computer skills, and strong research acumen.[21] Although our study strengthens the findings of the aforementioned study, we add to the discussion by introducing the concept of a collaborative-first approach. We found collaboration to be the driving factor for the explosive growth of our program.

**Mature Phase**

The mature phase represents the pinnacle of the program's development and is the result of the culmination of efforts to establish a long-lasting program. At this point, the productivity cycle has matured, revealing three distinct periods. Starting from the emerging productivity phase, we identified the first, second, and third year of the cycle as the recovery period, the acquisition period, and the production period, respectively.

The recovery periods reveal a systematic organized process that increases academic productivity over time, a product from the effective utilization of research resources to address previous challenges. It is essential for reflection, evaluation, and adjustment, allowing time for the team to recharge and prepare properly. The acquisition period of research is the phase at which resources, materials, and assets are acquired to provide solutions to the identified challenges or to set up execution of high-quality research. Activities may include building large databases, executing institutional review board activities, collecting data, analyzing, writing grants, and submitting manuscripts. The production period is the result of

executing carefully planned projects in addition to the baseline academic output.

By disseminating insights into the cycle of productivity, we reveal that more time is needed for high-impact research and that recovery and acquisition periods are essential for productivity bursts, as they contribute to the growth of the program longitudinally. Our commitment to high-impact research fosters strong research development, potentially contributing to our consistent match rate.

**The Positive Impact of Leadership: Transformation to the Collaborative-First Approach**

Although the CRF was initially designed to provide support for one to two interested senior medical students or residents in plastic surgery, it has since transformed into a program with a collaborative-first approach. The results of the strategic decision are notable after 2016, where an increase in external collaborations is seen. Several leadership changes occurred during this period, encompassing the change in clinical research program director, clinical research coordinator, and the division of plastic surgery program director, alongside the introduction of three new leaders within the division. These changes, combined with the expanded research team, significantly enhanced the capacity of the program to collaborate with external institutions. Based on the presented data, we second the sentiment of Carney et al[9] about how decisive leadership focused on research is critical for setting the academic tone of an institution's research program, and how without it, fewer benefits may be acquired.

**Power of External Collaborations**

We highlight the importance of creating a strong infrastructure before attempting a collaborative-first model when building the optimal CRF program. To our knowledge, there are no previous studies that specifically examine the associations between external collaborations and the scholarly impact of a growing CRF program.[21]

Our data demonstrate a positive correlation between external collaborations and academic output, journal diversity, and journal impact. The results show that cross-institutional and multidisciplinary collaborations are necessary for enhanced quality and diversification of research in plastic surgery. The program's evolution and deliberate engagement with multiple disciplines, as evidenced by the depth of our collaborative networks, result in greater research impact and academic output. This program has evolved to one that fosters multidisciplinary and multi-institutional collaborations, cultivating an abundance of research into the field.

**Long-term Impact of the CRF**

Beyond its critical role in residency selection, the CRF greatly impacts the professional development of every RF who has completed the program. Although it is a natural thought to assume graduated RFs would later obtain a PhD, it is noteworthy that none of our RFs pursued this route. This may be attributed to the fact that one can achieve their plastic surgery career without a PhD, and the combined time of completing a PhD and plastic surgery requires immense commitment.

Other than fulfilling the requirements for match success, we emphasize the role of potentially life-long mentorship offered by the CRF. Mentoring can become a significant tool in shaping a mentee's career, and in return, may promote academia by fostering leadership and innovation. This study underscores the long-term impact of the CRF on academic benefits of a well-structured CRF program.

**Limitations**

We acknowledge that this study has limitations. First, we recognize our publication search may not be fully comprehensive because it was confined to one search engine database and did not account for any publications after the follow-up period. Our search did not include electronic print, suggesting our results may be an underestimate of the true number of publications. Second, our definition of academic productivity and research impact did not factor in clinical, educational, and leadership involvement. Although research is the main focus for most dedicated research training programs, engagement in clinical, educational, and leadership activities that did not result in research is no less important to the professional development of a surgeon-scientist. Although not necessarily a limitation, as the true impact of networking and collaboration made possible by CRFs is neither feasibly nor practically delineated, it is prudent to recognize this important secondary component of research that begets academic productivity and career success. We encourage future studies to assess objective measures of academic productivity for clinical, educational, and leadership activities. Third, correlation does not imply causation. The impact of some variables, such as mentorship and leadership style, was challenging to quantify. However, we put forth our utmost effort to quantify the outcomes of the aforementioned strategic decisions, assessing collaborations by way of explanation.

## CONCLUSIONS

We highlight the importance of creating a strong infrastructure before attempting a collaborative-first model when building the optimal CRF program. As result of institutional support and our strategic decision to engage complimentary collaborators across multiple disciplines, there is discernible improvement in measurable impact, contributing to the growth of our multidecade program. We emphasize the benefit of going outside of the scope, folding in expertise and innovative methodologies to help apply new knowledge, solve clinical problems, improve performance, and provide quality care. Dedicating resources to foster deeper collaborations can enrich the field of plastic surgery research, recognizing that this investment fuels the cycle of productivity, offering promising returns to the future.

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## DISCLOSURES

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*This study adheres to the ethical standards and guidelines of the Declaration of Helsinki. No institutional review board approval was needed. All data presented in this study were deidentified and publicly available.*

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