Fat Grafting: A Citation Analysis of the Seminal Articles

Cormac W. Joyce MB, BCh*, Kenneth M. Joyce MB, BCh*, George Rahmani MB, BCh*, Stewart R. Walsh, MD†, Sean M. Carroll, MD‡, Alan J. Hussey, MD*, Jack L. Kelly, MD*

Background: There has been substantial rise in the volume of published works on fat transfer in the medical literature in the past 25 years, and this is indicative of its growing popularity. However, many unanswered questions remain, and there is no consensus as to the optimum technique. Consequently, the scientific and clinical research on fat grafting continues to increase rapidly. The purpose of our study was to perform a bibliometric analysis of the most-cited articles in fat transfer.

Methods: Through the Web of Science, all articles relating to fat grafting were identified in the plastic and reconstructive literature. The 100 most-cited articles were identified and analyzed individually.

Results: Total citations ranged from 35 to 363 and the most-cited paper by Sidney Coleman was published in Plastic and Reconstructive Surgery. The United States produced 46% of the most-cited papers, and the University of California was the most prolific institution. Twenty-one articles focused on lipofilling to the face while 14 articles looked at fat grafting to the breast.

Conclusions: The scientific relevance of a published work is reflected in the number of citations from peers that it receives. Therefore, the 100 most-cited papers in fat grafting have been the most influential articles on this field, and they are likely to be the ones that are remembered most. (Plast Reconstr Surg Glob Open 2015;3:e295; doi: 10.1097/GOX.0000000000000269; Published online 27 January 2015.)

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flawed system. The role of the citation is to recognize other authors for their influential and pertinent articles that they have previously published. The relative impact of a published body of work is reflected in the actual number of citations from peers that it receives, so that its scientific relevance increases with an increasing citation count.

In an era where “publish or perish” is increasingly apparent, the number of citations is being used to determine how grants and subsidies are awarded. The number of citations is of critical importance to the journal also, as the more citations that a particular article receives, the greater the impact factor (IF) of the journal. The IF was devised to facilitate comparisons between journals within specific fields of academic interest. It is a measure that is indicative of the average number of citations of recent articles published by the journal. The higher the IF, the more influential and noteworthy the journal is apparently deemed. Notwithstanding the obvious flaws associated with the IF system, it is still widely regarded as the best available mode of gauging the merits of specific publications.

For a given year, the IF can be calculated by averaging the number citations received per article published in that journal during the preceding 2 years.

A citation analysis is a bibliometric method that describes the means of analyzing the citation history of published articles. The purpose of this study was to identify the 100 most-cited articles relating to fat grafting in the medical literature and to carefully analyze each article individually looking at the article type, year of publication, authorship, country of origin, institution, and level of evidence.

**MATERIALS AND METHODS**

Eighteen international journals were included in our citation analysis, and these were selected based on an overall consensus reached by 2 of the authors. The publications included 10 well-known plastic and reconstructive journals and 8 high IF surgical journals (Table 1). The 8 surgical journals were included as there was agreement by the authors that these would be the most likely to publish articles pertaining to fat grafting.

The Institute of Scientific Information produces the Web of Science (Thomson Reuters, NY, N.Y.), and this facilitates access to the Science Citation Index, MEDLINE, and other citation indices, which collectively index more than 12,000 journals. Using this electronic database, we were able to identify the most-cited articles on fat grafting from 1945 to 2014 in our chosen journals.

All Web of Science (Thomson Reuters) indexed articles from the 18 journals were combined in our search and the resulting articles (144,246 in total) were then ranked in order of times cited. To locate articles relating to fat grafting, specific keywords were added separately into the Web of Science (Thomson Reuters) database and the chosen 18 journals were searched. The keywords used were “fat,” “fat transplant,” “fat graft,” “lipotransfer,” “lipoaspirate,” “adipocyte,” and “adipose stem cells.” The filtered results were examined by 2 of the authors independently looking for articles on fat grafting. An article was only selected for further analysis if both authors agreed it was suitable. The 100 most-cited articles on fat grafting were then chosen for further analysis. Each individual article was analyzed looking at its subject matter, authorship, article type, country of origin, institution, year of publication, and level of evidence.

**RESULTS**

The top 100 articles on fat grafting are in descending order based on citation number in Table 2. Citation numbers ranged from 35 to 363, with a mean of 83 ± 60.7. Eighteen international journals were initially included for analysis in our study but only 6 journals contributed articles to the 100 most-cited list (Table 1). These included 5 specialist plastic and reconstructive journals: *Plastic and Reconstructive Surgery (PRS)*, *Aesthetic Plastic Surgery, Clinics in Plastic Surgery, Annals of Plastic Surgery, and Journal of Plastic, Reconstructive and Aesthetic Surgery*. The only general surgery journal that contributed to the top 100 was the *American Journal of Surgery*. Fifty-one percent of articles originated from *PRS* while *Aesthetic Plastic Surgery* produced 23 articles. The *Annals of Plastic Surgery* produced 12 articles while *Clinics in Plastic Surgery* had 10 articles in the top 100.

The article with the highest citation number was written by Coleman, and it has been cited 363 times

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**Table 1. The Journals and the Number of Articles Each Journal Contributed to the Top 100 Most-cited Articles on Fat Grafting**

| Journal                                      | No. Articles in Top 100 |
|----------------------------------------------|-------------------------|
| Plastic and Reconstructive Surgery           | 51                      |
| Aesthetic Plastic Surgery                    | 23                      |
| Clinics in Plastic Surgery                   | 10                      |
| Annals of Plastic Surgery                    | 12                      |
| Journal of Plastic, Reconstructive and       | 3                       |
| Aesthetic Surgery                            |                         |
| American Journal of Surgery                  | 1                       |

*The Annals of Surgery, British Journal of Surgery, Surgery, American Journal of Surgery, Aesthetic Surgery Journal, Archives of Facial Plastic Surgery, British Journal of Plastic Surgery, Canadian Journal of Plastic Surgery, European Journal of Plastic Surgery, Journal of the American College of Surgeons, Journal of Plastic Surgery and Hand Surgery, and Scandinavian Journal of Plastic Surgery and Reconstructive Surgery* were included in the search, but they did not contribute to the top 100.
Table 2. The List of 100 Most-cited Articles on Fat Grafting

| Rank | Author                  | Citations | Rank | Author                  | Citations | Rank | Author                  | Citations |
|------|-------------------------|-----------|------|-------------------------|-----------|------|-------------------------|-----------|
| 1    | Coleman                 | 363       | 34   | Lu et al                | 79        | 67   | Chan et al              | 50        |
| 2    | Coleman                 | 258       | 35   | Dragoo et al            | 77        | 68   | Toledo                  | 50        |
| 3    | Billings and May        | 257       | 36   | Guerrerosantos et al    | 75        | 69   | Torio-Padron et al      | 49        |
| 4    | Ersek                   | 225       | 37   | Dudas et al             | 75        | 70   | Har-Shai et al          | 49        |
| 5    | Mizuno et al            | 215       | 38   | Gutowski                | 74        | 71   | Zheng et al             | 46        |
| 6    | Coleman                 | 215       | 39   | Kaufman et al           | 71        | 72   | Coleman                 | 45        |
| 7    | Yoshimura et al         | 211       | 40   | von Heimburg et al      | 70        | 73   | Pereira and Radwanski   | 45        |
| 8    | Coleman                 | 209       | 41   | Moore et al             | 69        | 74   | Pu et al                | 44        |
| 9    | Ashjian et al           | 197       | 42   | Teimourian              | 69        | 75   | Feinendegen et al       | 44        |
| 10   | Peer                    | 189       | 43   | De Ugarte et al         | 68        | 76   | Wolter et al            | 43        |
| 11   | Coleman and Saboeiro    | 186       | 44   | Carraway and Mellow     | 68        | 77   | Schoeller et al         | 43        |
| 12   | Niechajev and Sevcuk    | 184       | 45   | Pu et al                | 68        | 78   | Guerrerosantos et al    | 41        |
| 13   | Chajchir and Benzaquen  | 150       | 46   | Chajchir and Benzaquen  | 67        | 79   | Mojallal et al          | 41        |
| 14   | Ellenbogen              | 136       | 47   | Fagrell et al           | 63        | 80   | Gonda et al             | 41        |
| 15   | Illouz                  | 129       | 48   | Moscona et al           | 63        | 81   | Hudson et al            | 41        |
| 16   | Katz et al              | 127       | 49   | Bircoll and Novack      | 63        | 82   | Serra-Renom et al       | 40        |
| 17   | Moseley et al           | 113       | 50   | Kurita et al            | 63        | 83   | Serra-Renom and Fontdevila | 40    |
| 18   | Smith et al             | 110       | 51   | Stoch and Mao           | 59        | 84   | Khouri and Del Vecchio  | 39        |
| 19   | Rohrich et al           | 109       | 52   | Carpaneda and Ribeiro   | 59        | 85   | Rigotti et al           | 39        |
| 20   | Kononas et al           | 107       | 53   | Eppley et al            | 59        | 86   | Lu et al                | 39        |
| 21   | Coleman                 | 102       | 54   | Ramon et al             | 58        | 87   | Gonzalez et al          | 39        |
| 22   | Bircoll                 | 101       | 55   | Klinger et al           | 58        | 88   | Cárdenas-Camarena et al | 37        |
| 23   | Hör et al               | 100       | 56   | Guerrerosantos et al    | 58        | 89   | Baran et al             | 38        |
| 24   | Lee et al               | 99        | 57   | Tholpady et al          | 58        | 90   | Hyakusoku et al         | 37        |
| 25   | Spear et al             | 90        | 58   | Carpaneda and Ribeiro   | 57        | 91   | Marra et al             | 36        |
| 26   | Schipper et al          | 90        | 59   | Chajchir et al          | 56        | 92   | Trepsat et al           | 36        |
| 27   | Yuksel et al            | 87        | 60   | Ersek et al             | 55        | 93   | Castello et al          | 36        |
| 28   | Loeb                    | 86        | 61   | Guerrerosantos et al    | 54        | 94   | Lewis et al             | 36        |
| 29   | Kaufman et al           | 82        | 62   | Chajchir et al          | 54        | 95   | Pinsolle et al          | 35        |
| 30   | Boschert et al          | 81        | 63   | Zhu et al               | 53        | 96   | Loeb et al              | 35        |
| 31   | Illouz                  | 80        | 64   | Ullmann et al           | 53        | 97   | Zocchi and Zuliani      | 35        |
| 32   | Matsudo and Toledo      | 80        | 65   | Kesselring             | 53        | 98   | Toledo and Mautad       | 35        |
| 33   | Peer                    | 79        | 66   | Illouz and Sterodimas   | 52        | 99   | Vaienti et al           | 35        |
|      |                         |           |      |                         |           | 100 | Locke and de Chalain    | 35        |
to date. This article, published in Clinics in Plastic Surgery in 1997, was a landmark article insofar that it was one of the first modern-day descriptions of lipofilling to the face using the Coleman method of fat transfer.45 The oldest article in the top 100 was from 1950 and written by Peer.38 It is the 10th most-cited article (189 citations) and was published in PRS. This early article on fat transfer, in which Peer postulates on the “cell survival theory,” describes the mixed results he encountered when a group of individuals were fat grafted. The most recent article in the top 100 was written by Rigotti et al67 and published in August 2010 in Aesthetic Plastic Surgery. This article examined the perceived oncological risk in fat transfer to the breast for postmastectomy patients. The decade that contributed the most articles to the top 100 articles on fat grafting was the 2000s with 53 articles (Table 3). Eighty-five percent of the top articles were published since 1990, thereby highlighting the recent surge in fat grafting procedures.

To facilitate the analysis of the characteristics of each article, the 100 articles were placed into 4 different categories based on the anatomical location of the fat grafting (Table 4). Twenty-one articles focused on lipotransfer to the face while 20 articles looked at fat grafting to the breast. Fourteen articles described fat transfer to contour defects of the trunk, and one solitary article looked at fat grafting to the hands. Sixty-five articles in the top 100 were clinical, and the remainder was laboratory-based including animal studies. Seven articles were review articles, whereas 2 articles were published correspondence to the editor of that particular journal.36,53 One of the letters to the editor reported on a rare case of blindness following fat grafting to the face,36 whereas the other letter by Illouz53 reports on his early experience of lipotransfer from 1983. The majority of the studies in the top 100 were level IV or V evidence (77%) while there was no level I studies (Table 5).

The top 100 most-cited articles in fat grafting originated from 18 countries, with the United States contributing the most with 46 articles (Fig. 1). Brazil produced 8 articles while Mexico, Japan, and France
Table 7. The Authors Who Contributed Most Articles to the Top 100 List

| Author             | No. Citation Classics | Position on Author List |
|--------------------|-----------------------|-------------------------|
| Coleman            | 8                     | First author—7, second author—1 |
| Hedrick            | 7                     | Third author—2, fourth—1, sixth—1, seventh—2, ninth—1 |
| Guerresantos       | 5                     | First author—4 |
| Chajchir           | 4                     | First author—4 |
| Rubin              | 4                     | Fourth author—1, fifth—1, seventh—1, eighth—1 |
| Zhu                | 4                     | Second author—1, third—1, fifth—1 |
| Benham             | 3                     | Fifth author—1, eighth—2 |
| Benzaquen          | 3                     | Second author—3 |
| De Ugarte          | 3                     | First author—1, fourth—1 |
| Illouz             | 3                     | First author—3 |
| Marra              | 3                     | Second author—2 |
| Ogawa              | 3                     | Second author—1, fourth—1, fifth—1 |
| Pu                 | 3                     | First author—2, eighth—1 |
| Sato               | 3                     | Second author—1, fourth—1 |
| Toledo             | 3                     | First author—2, second—1 |
| Ullman             | 3                     | First author—1, second—1, eighth—1 |
| Zuk                | 3                     | Second author—1, sixth—2 |
| Ashjian            | 2                     | First author—1, second—1 |
| Beach              | 2                     | Fourth author—1 |
| Bircoll            | 2                     | First author—2 |
| Bradley            | 2                     | Second author—1, seventh—1 |
| Brown              | 2                     | Third author—1, seventh—1 |
| Carpaneda          | 2                     | First author—2 |
| Elbarbary          | 2                     | Second author—1, third—1 |
| Ersek              | 2                     | First author—2 |
| Futrell            | 2                     | Fourth author—1, fifth—1 |
| Gonda              | 2                     | First author—1, fifth—1 |
| Har-Shai           | 2                     | First author—1, third—1 |
| Hirshowitz         | 2                     | Fourth author—1, fifth—1 |
| Hyakusoku          | 2                     | First author—1, sixth—1 |
| Katz               | 2                     | First author—1, sixth—1 |
| Kaufman            | 2                     | First author—2 |
| Kurita             | 2                     | First author—1, fourth—1 |
| Lindenbaum         | 2                     | Second author—1, sixth—1 |
| Llull              | 2                     | Second author—2 |
| Matsumoto          | 2                     | Second author—1, fourth—1 |
| Miller             | 2                     | Second author—1, tenth—1 |
| Mizuno             | 2                     | First author—1, second—1 |
| Peer               | 2                     | First author—2 |
| Schipper           | 2                     | First author—1, sixth—1 |
| Serra-Renom        | 2                     | First author—2 |
| Ribeiro            | 2                     | Second author—2 |
| Rohrich            | 2                     | First author—1, sixth—1 |
| Shigeura           | 2                     | Second author—1, third—1 |
| Sorokin            | 2                     | Second author—1, fifth—1 |
| von Heimburg        | 2                     | First author—1, second—1 |
| Wasson             | 2                     | Fifth author—2 |
| Yoshimura          | 2                     | First author—1, twelfth—1 |

published 5 articles each. The institution that produced the most articles was the University of California system with 8 articles (Table 6), whereas the New York University School of Medicine published 7 articles. Eleven authors were first-named authors on more than 1 article (Table 7), whereas 48 authors contributed to more than 1 article overall. The most illustrious author was Coleman as he was first-named author on 7 articles while Guerresantos and Chajchir were first-named authors on 4 articles each.

The second most-cited article in the top 100 was another article by Coleman, and this has been cited 258 times to date. This article retrospectively examined over 400 fat injections to the face and compared it to a control. This article was the first article detailing the Coleman technique for fat transplantation. The third article on the most-cited list was a review on fat grafting written by Billings and May and published in PRS. This 1989 article revisited the topic of fat grafting as it had been a seemingly neglected topic for many years in plastic surgery, most likely due to unpredictable results coupled with an absence of a clear understanding of how it worked.

At number 7 in the top 100 list, Yoshimura et al described a novel technique for breast augmentation using lipoinfiling in conjunction with cell-assisted transfer. They found that postoperative fat atrophy was negligible compared to fat grafting alone. The 14th most-cited article was published in the Annals of Plastic Surgery in 1986. This article by Ellenbogen was a preliminary report on the use of fat as a facial filler, and it has been cited 136 times to date.

At number 19, Rohrich et al examined the role of centrifugation along with harvest site in fat grafting. As fat grafting yields such unpredictable results with varying amounts of fat resorption, there have been numerous attempts at refining the technique. Proposed measures to improve fat survival include centrifugation and fat harvest from certain anatomical sites. Rohrich et al found that centrifugation had no effect on fat viability, and neither was there any difference in adipocyte viability between several donor sites.

Results from the “Autologous fat transfer national consensus survey” were at 29. This article published the results of a survey of 508 plastic surgeons. The aim of the survey was to assess their technique used in fat grafting and ascertain their level of success with their chosen method. Overall, most surgeons did not deviate from published methods of fat grafting, and 80% of them were happy with the long-term results.

The American Society of Plastic Surgeons Fat Graft Task Force was set up in 2007 to conduct an assessment regarding the efficacy and safety of autologous fat grafting. The recommendations put forward by this task force were at number 38 in the most-cited list. This article detailed the evidence-based practice recommendations put forward by the task force on fat transfer. At number 55, Klinger et al reported on their experience with fat grafting of burn wounds. Using the Coleman fat transfer method, scars from burns were injected and reviewed at
6 months whereby histological examination demonstrated changes suggestive of tissue regeneration.

At 90th position in the top 100, Hyakusoku et al reported on the complications associated with autologous fat injection to the breast, including calcifications and cysts. Furthermore, they also observed that routine breast cancer screening would detect abnormalities following fat grafting.

**DISCUSSION**

Fat transfer is now an invaluable tool in the plastic surgeon’s armamentarium, and its growth in popularity is echoed in the large volume of published material. The purpose of our study was to identify the 100 most-cited articles in fat grafting and to further analyze each article individually. As the citation count of an article is a reflection of its influence on a particular field, the most-cited articles in fat transfer are the published works that have made the biggest impact on our specialty. The top 100 list contains articles that represent most of the key moments in the evolution of fat grafting written by illustrious authors who are well-recognized experts in the art of fat transfer.

Despite the fact that most of the key articles on fat grafting are present on our top 100 list, several landmark articles have failed to be included in the top 100. This may be explained by the phenomenon of “obliteration by incorporation,” whereby “classic articles” fail to be cited over time as they have become such common knowledge. A prime example of this is the 2012 article by Khouri et al, which reports on the dual use of lipotransfer and the Brava (Brava, LLC, Miami, Fla.) device for breast augmentation. Despite being a well-known article with over 30 citations, it failed to make it in to the top 100.

A study of this nature is not without limitations, however. Several biases exist with bibliometric analyses, including self-citation, journal bias, in-house bias, and omission bias, whereby academic competitors are purposely not cited. Incomplete citing is a considerable limitation that occurs when citations are made to persuade the reader rather than recognizing key works in that particular area.

It is argued that the most influential articles that have made the most impact on a specific specialty can be found on the reference list of their most-cited articles. It has also been proposed that older articles have a higher citation count than more recent articles based on a longer citable period. Scientific articles tend not to be cited frequently until 2 years after publication and usually reach a maximum after 3–10 years after which they continue to be cited, albeit at a slower rate. Consequently, several methods have been devised to remedy this perceived bias. The citation index, as described by Loonen et al, was defined as the average number of times an article has been cited per year up to 16 years after publication. Sixteen years was accepted as the critical citable period as they found that the most significant change in annual increase of the fraction of citations occurred at this time point. For articles that had been published within the last 16 years, the total citation number since publication was divided by the number of years since publication. However, we have found that the citation index heavily favors more recently published articles and several reasons account for this. The growing utilization of electronic citation managers (ie, EndNote, Thomson Reuters) facilitates rapid incorporation of references into modern-day articles, which would not have been as readily achievable in previous years. Also, most recent published works tend to be available online and are therefore much more accessible than older articles that often require significant effort to locate.

Eighty-five percent of the top 100 articles were published in the past 24 years, and this highlights how fat grafting has soared in popularity in recent times. It is important to recognize the contribution Peer made to fat transfer as his seminal work was published in the 1950s in an era when fat grafting was not commonplace. It is a testament to his work that 2 of his articles are in the top 100.

There is a paucity of studies in plastic surgery with high levels of evidence. The majority of the clinical studies in the top 100 most-cited list were level IV or V evidence, which is in keeping with what Loonen et al found when they analyzed the characteristics of the top 50 articles in plastic surgery. In contrast to medicine, surgery by its very nature does not lend itself to randomized control trials, as it is difficult to standardize surgical procedures. Furthermore, a limited disease incidence coupled with the variation in experience and expertise between surgeons renders surgical procedures less suitable for level I studies. The intended outcome in fat grafting is for an aesthetically pleasing result with added volume. Therefore, the level IV and V studies published on fat grafting are as important to this field as the higher level of evidence studies are to other disciplines.

The top 100 list contains articles that document the entire history of fat grafting. Bircoll and Coleman are widely attributed with pioneering the procedure in the 1990s, and as such, both authors are well represented in the top 100 list. Although several articles predate the work of Bircoll and Coleman, they are largely responsible for the surge in popularity of fat grafting. The Coleman technique for fat grafting is one of the most commonly employed techniques for fat transplantation, yet numerous other techniques have been published. The results of the varied different techniques...
for fat grafting are quite similar, thus indicating that no one technique is superior. The Coleman technique of low-volume lipofilling is in stark contrast to the mega-volume fat transfer described by Khouri et al.118

Despite having a better understanding of fat grafting today than we did in the 1950s, there still remain many unanswered questions.115 No consensus has been reached on the optimum technique for any of the 3 steps in fat transfer: harvesting, processing, and lipofilling.119 This is highlighted by the fact that there are so many laboratory-based animal studies in the top 100 list which seek to find the answer to optimizing adipocyte viability. Refinements in the technique of fat grafting have yielded improved results, yet there remains a huge discrepancy in outcomes between patients. Despite this, it is a rapidly evolving field within plastic surgery, and it has transformed clinical practice in recent years. Although it was first described more than 120 years ago, fat transfer still remains in its infancy due to its neglect for so many years. The number of indications for fat grafting continually grows as it becomes used in a plethora of conditions.120-122 This is evident in the expanding medical literature that continuously reports on newly unearthed benefits of fat grafting,123 which, in turn, further drives scientific research.

CONCLUSIONS

The top 100 list generated from our analysis not only identifies the landmark papers that have had the most influence on fat grafting but also acknowledges the most prolific authors and institutions that have contributed papers to the list. Many articles described pioneering methods and techniques that are still used today. Citation analysis is certainly not a measure of scientific quality and certain intrinsic limitations exist with it. However, it does provide an objective and quantitative measure of the impact that an article has on its respective field. More importantly, it provides useful information on readership. The top 100 papers on fat grafting were all written by experts in the field and their importance is reflected in the large number of citations they received from their peers.
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