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Highly Cited Articles in Periacetabular Osteotomy Research

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Purpose: The aim of this study is to identify highly cited articles and examine trends and characteristics in research on periacetabular osteotomy.
Materials and Methods: The 50 most highly cited articles on periacetabular osteotomy research were identified using Scopus. Data regarding article demographics and publication were collected from each article and an analysis was performed.
Results: The mean citation count was 125±37. The article with the highest total citation count (796), five-year citation count (327), and five-year citation density (65/year) was reported by Reinhold Ganz. The five-year citation density showed strong correlation with total citation density (r=0.930, *P*<0.001). Reinhold Ganz, the most productive author, was listed on 13 articles in the cohort with 455 weighted citation points.
Conclusion: This study provides a collection of articles examining periacetabular osteotomies and demonstrates that citation count can be regarded as an acceptable measure of the contemporary academic influence of an article.

Key Words: Hip dysplasia, Periacetabular osteotomy, Cited

INTRODUCTION

Hip dysplasia, with an estimated prevalence of 0.1% of the population, is a significant predictor of osteoarthritis, and is observed in up to 40% of patients with hip osteoarthritis[1-4]. Early intervention for management of hip dysplasia can potentially limit hip osteoarthritis and prevent or delay future total hip replacement[5,6]. Various osteotomies have been proposed in the literature in an effort to increase acetabular coverage of the femoral head and provide more even distribution of weight-bearing forces across the acetabulum[7,8]. The Bernese periacetabular osteotomy (PAO) was introduced in 1988 for use in patients with skeletal maturity[9]. The PAO is the predominant non-arthroplasty choice for surgeons in treatment of adult acetabular dysplasia[10]. Nevertheless, discussion of different approaches and minimally invasive techniques is provided in the literature[11].

Considering the prevalence of the PAO in treatment of hip dysplasia with recent advancements reported in the literature, conduct of a citation analysis of literature on PAO is justified[11,12]. Use of citation analyses as a method for collecting and identifying impactful studies has been validated across many scientific and medical fields[13,14]. The emphasis of citation analyses on citation count–which is predic-

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tive of the overall impact of an article–allows authors to present empirical and subjective findings regarding the most influential works related to a topic[15]. Citation analyses have been performed across all fields of orthopaedics, including various procedures, however no citation analysis on PAO has been reported to date[16-21]. In an effort to address this paucity, the aim of this study is to conduct a citation analysis of the literature on PAO in order to identify patterns and characteristics of both historically influential studies, as well as more recent breakthrough studies which are leading change within the field.

MATERIALS AND METHODS

A literature search of articles on analysis of PAO was performed using Scopus (Elsevier, Amsterdam, The Netherlands) on August 17, 2021 using the terms "periacetabular osteotomy" OR "PAO" to search "article title, abstract, and keywords" of all primary and review articles. Scopus, which contains a large collection of peer reviewed articles, is under constant re-evaluation in order to ensure that only the most reliable scientific articles and content are displayed. A thorough review of all search results was performed in order to ensure appropriateness for inclusion in this study. Articles that appeared to be unrelated were excluded from consideration. An analysis of the top 50 remaining articles was then performed. Article title, journal, authors, institution, country of origin, year of publication, total citation count, citation count from the last five years, total citation density (2020-year of publication), and five-year citation density were collected for each article.

Assessment of the level of evidence for each article was performed in accordance with the guidelines of The *Journal of Bone and Joint Surgery* or recorded directly from the abstract, if stated[22]. The gross analysis of authorship consisted of calculating the number of articles by each author in the cohort. A weighted analysis was also performed by assigning 50 points to each author of the most cited article, with a decrease in one point awarded to the authors of each subsequently ranked article. Total points were summed, and a weighted score was generated. The relative author position for each article was not factored into the analysis. The h-index score for each author was collected using Scopus.

These data were assessed for normality using a Q-Q plot and the Shapiro–Wilk test, both of which confirmed that these data did not show a normal distribution. Therefore, an assessment for a significant association between citation counts and densities and level of evidence was performed using rhe Kruskal–Wallis test, which is a non-parametric alternative to ANOVA. The Kruskal–Wallis test does not assume normality and therefore compares the medians of the sample groups. Results of comparison of medians across groups showed no statistically significant difference. Comparison of total citation count and total citation density, total citation count and 5-year citation density, total citation density and 5-year citation density, years since publication and total citation density, and years since publication and total citation count was performed using Spearman's correlation. IBM SPSS Statistics (ver. 23; IBM, Armonk, NY, USA) was used in performance of all calculations and statistical analyses. *P*-values less than 0.05 were statistically significant.

RESULTS

The mean total citation count was 125±37, with a total mean citation density of 9±2. The mean five-year citation count was 56±15, with a mean five-year citation density of 11±3. The article containing the highest total citation count (796), five-year citation count (327), and five-year citation density (65/year) was reported by Ganz et al.[9]. The article containing the highest total citation density (30/year) was reported by Siebenrock et al.[23]. The most frequent level of evidence was IV with 36 articles. None of the studies included in the top 50 cited were level of evidence I (Table 1, 2)[9,11,23-70].

Five-year citation density showed strong correlation with total citation density (r=0.930, $P<0.001$). Medium strength correlations were observed between both total citation density and total citation count (r=0.553, $P<0.001$), five-year citation density and total citation count (r=0.592, $P<0.001$), and total citation count and years since publication (r=0.498, $P<0.001$). A weak negative correlation was observed between five-year total citation density and years since publication (r=–0.329, $P=0.019$) (Fig. 1-5).

The year of publication ranged from 1988 to 2017, with a median of 2006. The greatest number of articles was reported in 1999, with 10 articles in the cohort, followed by 2009 with five articles. One article was reported in the 1980's, 12 articles in the 1990's, 24 articles in the 2000's, and 13 articles from 2010 to 2019. Based on this information, attention on research regarding the PAO has increased in recent decades. Within the cohort, the greatest number of articles was reported by *Clinical Orthopaedics and Related Research*, with 23 articles, followed by the *Journal of Bone and Joint Surgery - Series A*, with 17 articles.

Reinhold Ganz, from Bern, Switzerland, the most produc-

Table 1. Top 50 Articles of Periacetabular Osteotomy Research

Study	Citations (CD)	Citations in last 5 years (CD)	Level of evidence	Publishing journal	Nationality of leading author
Ganz et al.[9] (1988)	796 (25)	327 (65)	IV	*Clinical Orthopaedics and Related Research*	Switzerland
Siebenrock et al.[23] (2003)	509 (30)	121 (24)	IV	*Journal of Bone and Joint Surgery - Series A*	Switzerland
Steppacher et al.[24] (2008)	335 (28)	224 (45)	III	*Clinical Orthopaedics and Related Research*	Switzerland
Myers et al.[25] (1999)	308 (15)	97 (19)	IV	*Clinical Orthopaedics and Related Research*	Switzerland
Trousdale et al.[26] (1995)	277 (11)	41 (8)	IV	*Journal of Bone and Joint Surgery - Series A*	Switzerland
Siebenrock et al.[27] (1999)	250 (12)	75 (15)	IV	*Clinical Orthopaedics and Related Research*	Switzerland
Cunningham et al.[28] (2006)	172 (12)	52 (10)	II	*Journal of Bone and Joint Surgery - Series A*	United States of America
Clohisy et al.[29] (2009)	158 (14)	111 (22)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Matheney et al.[30] (2009)	155 (14)	97 (19)	II	*Journal of Bone and Joint Surgery - Series A*	United States of America
Peters et al.[31] (2006)	154 (11)	69 (14)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Trumble et al.[32] (1999)	139 (7)	43 (9)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Clohisy et al.[33] (2005)	134 (9)	62 (12)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Davey and Santore[11] (1999)	127 (6)	46 (9)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Matta et al.[34] (1999)	124 (6)	47 (9)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Crockarell et al.[35] (1999)	121 (6)	38 (8)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Troelsen et al.[36] (2009)	111 (10)	71 (14)	II	*Journal of Bone and Joint Surgery - Series A*	Denmark
Clohisy et al.[37] (2007)	111 (9)	51 (10)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Hussell et al.[38] (1999)	111 (5)	36 (7)	IV	*Clinical Orthopaedics and Related Research*	United Kingdom
Albers et al.[39] (2013)	104 (15)	91 (18)	III	*Clinical Orthopaedics and Related Research*	Switzerland
Hussell et al.[40] (1999)	92 (4)	23 (5)	V	*Clinical Orthopaedics and Related Research*	United Kingdom
Kralj et al.[41] (2005)	90 (6)	33 (7)	IV	*Acta Orthopaedica*	Slovenia
Clohisy et al.[42] (2006)	86 (6)	46 (9)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Murphy et al.[43] (1999)	86 (4)	31 (6)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Langlotz et al.[44] (1997)	81 (4)	22 (4)	IV	*Computer Aided Surgery*	Switzerland
Ganz et al.[45] (2010)	79 (8)	45 (9)	V	*Clinical Orthopaedics and Related Research*	Switzerland
Naito et al.[46] (2005)	76 (5)	39 (8)	IV	*Clinical Orthopaedics and Related Research*	Japan

(Continued to the next page)

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Table 1. Continued

Study	Citations (CD)	Citations in last 5 years (CD)	Level of evidence	Publishing journal	Nationality of leading author
Murphy et al.[47] (2002)	75 (4)	19 (4)	III	*Clinical Orthopaedics and Related Research*	United States of America
Biedermann et al.[48] (2008)	72 (6)	47 (9)	IV	*International Orthopaedics*	Austria
Lerch et al.[49] (2017)	71 (24)	71 (14)	III	*Clinical Orthopaedics and Related Research*	Switzerland
Thawrani et al.[50] (2010)	70 (7)	47 (9)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Trousdale et al.[51] (2003)	70 (4)	24 (5)	V	*Acta Orthopaedica Scandinavica*	United States of America
Hartig-Andreasen et al.[52] (2012)	67 (8)	56 (11)	II	*Clinical Orthopaedics and Related Research*	Denmark
Yasunaga et al.[53] (2003)	67 (4)	20 (4)	IV	*Journal of Bone and Joint Surgery - Series A*	Japan
Zaltz et al.[54] (2014)	63 (11)	63 (13)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Matheney et al.[55] (2010)	62 (6)	44 (9)	II	*Journal of Bone and Joint Surgery - Series A*	United States of America
Troelsen et al.[56] (2008)	62 (5)	38 (8)	IV	*Journal of Bone and Joint Surgery - Series A*	Denmark
Clohisy et al.[57] (2017)	61 (20)	61 (12)	IV	*Journal of Bone and Joint Surgery - Series A*	United States of America
Mayo et al.[58] (1999)	61 (3)	16 (3)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Garras et al.[59] (2007)	59 (5)	24 (5)	IV	*Journal of Bone and Joint Surgery - Series B*	United States of America
Parvizi et al.[60] (2004)	59 (4)	29 (6)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Beck et al.[61] (2003)	56 (3)	19 (4)	IV	*Surgical and Radiologic Anatomy*	Switzerland
Siebenrock et al.[62] (2014)	53 (9)	53 (11)	IV	*Journal of Bone and Joint Surgery - Series A*	Switzerland
Fujii et al.[63] (2011)	51 (6)	34 (7)	IV	*Journal of Bone and Joint Surgery - Series B*	Japan
van Bergayk et al.[64] (2002)	49 (3)	16 (3)	IV	*Journal of Bone and Joint Surgery - Series B*	Canada
Wells et al.[65] (2017)	48 (16)	48 (10)	III	*Clinical Orthopaedics and Related Research*	United States of America
Ziebarth et al.[66] (2011)	48 (5)	29 (6)	IV	*Clinical Orthopaedics and Related Research*	Switzerland
Armiger et al.[67] (2009)	48 (4)	33 (7)	IV	*Acta Orthopaedica*	United States of America
Millis et al.[68] (2009)	47 (4)	22 (4)	IV	*Clinical Orthopaedics and Related Research*	United States of America
Kain et al.[69] (2011)	46 (5)	29 (6)	III	*Journal of Bone and Joint Surgery - Series A*	United States of America
Pogliacomi et al.[70] (2005)	76 (5)	10 (2)	IV	*Acta Orthopaedica Scandinavica*	Italy
Mean±SD	125±37 (9±2)	56±15 (11±3)			

CD: citation density, SD: standard deviation.

tive author, was listed on 13 articles in the cohort–two of which were first author–and had 455 weighted citation points. John Clohisy, from St. Louis, MO, had the highest number of first author articles in the cohort with five appearances as first author (Table 3). The United States of America had the highest number of articles, with 25 first authors, followed by Switzerland with 13 first authors. However, authors from Switzerland were the first authors of the six most highly cited articles.

DISCUSSION

The purpose of this study was to conduct a citation analysis of the 50 most highly cited articles found in the literature on PAO in order to highlight authors and article trends of the most influential work. Based on overall authorship and weighted citation points, Reinhold Ganz, from Bern, Switzerland, was found to be the most influential author. Considering Ganz's historical and current influence related to the PAO, this finding provides further validation of the utility of citation analysis for highlighting influential authors

Table 2. Mean Citation Count and Density for Each Level of Evidence

Level of evidence (total count)	Total citation count	5-Year citation count	Total citation density	5-Year citation density
Level II (5)	113±62	64±26	10.2±3.7	12.8±5.2
Level III (6)	113±116	80±79	15.3±10.0	16.1±15.3
Level IV (36)	132±50	53±18	8.1±2.1	10.5±3.6
Level V (3)	80±27	31±31	5.5±5.2	6.1±6.2

Values are presented as mean±standard deviation.

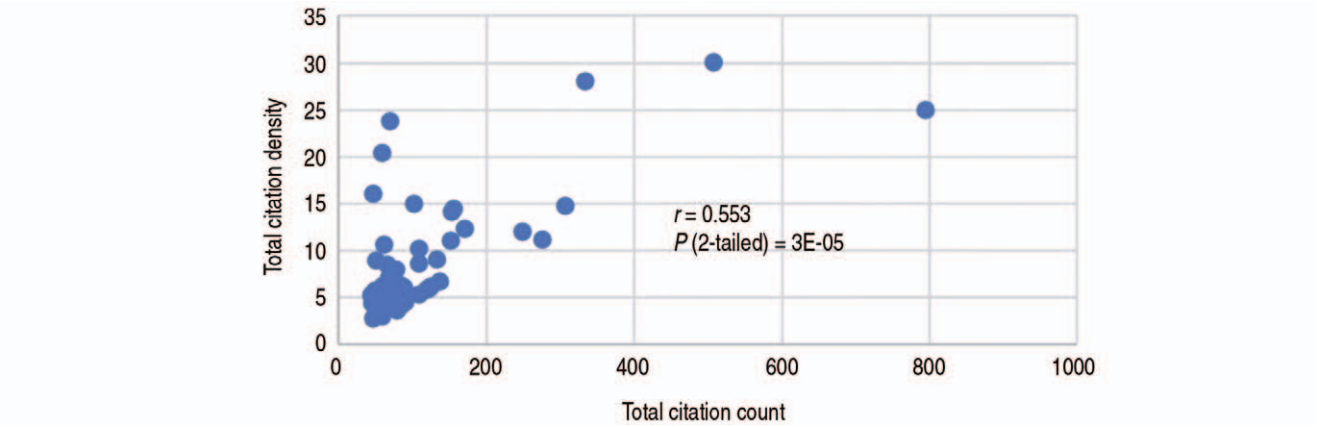

Fig. 1. Relationship of total citation count and density.

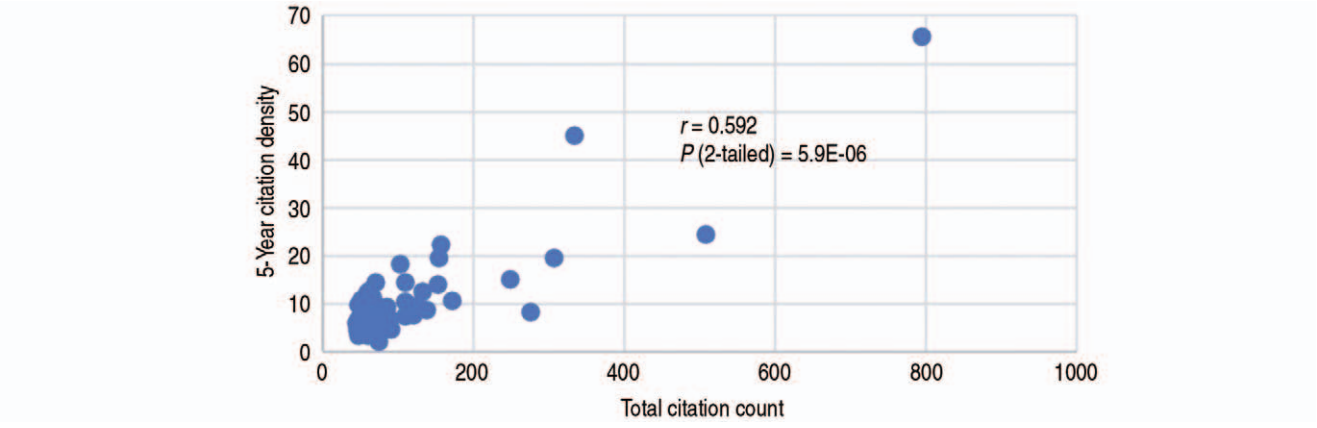

Fig. 2. Relationship of total citation count and 5-year citation density.

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and works.

Studies conducted in order to examine therapeutic outcomes and complication rates represent a substantial portion of the influential literature on PAO. Overall, 30 of the articles focused on therapeutic outcomes following PAO in general and 13 articles specifically focused on complications. This finding is in contrast with those of other citation analyses, such as those for hip and knee arthroplasty, which reported an increased focus on perioperative management[17].

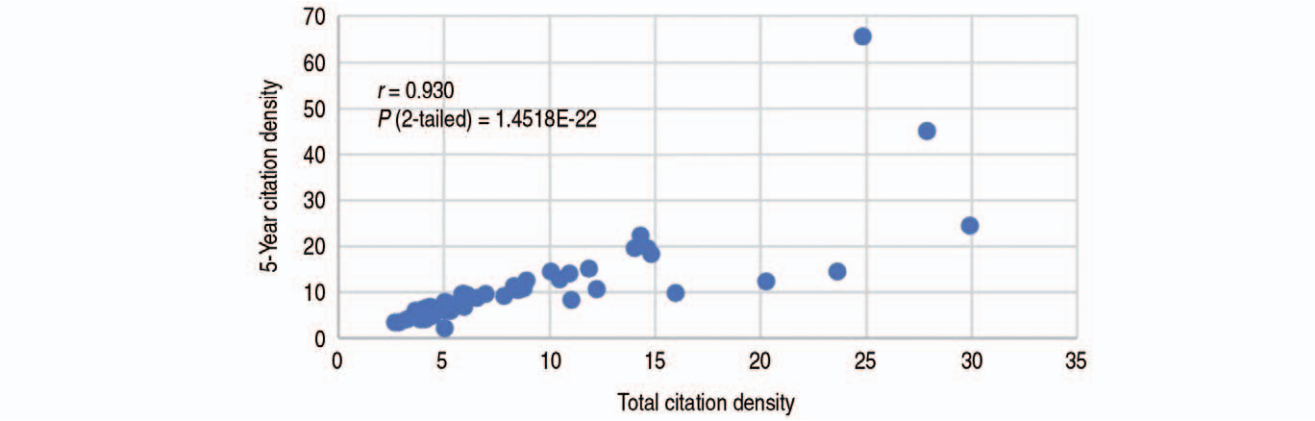

Fig. 3. Relationship of total citation density and 5-year citation density.

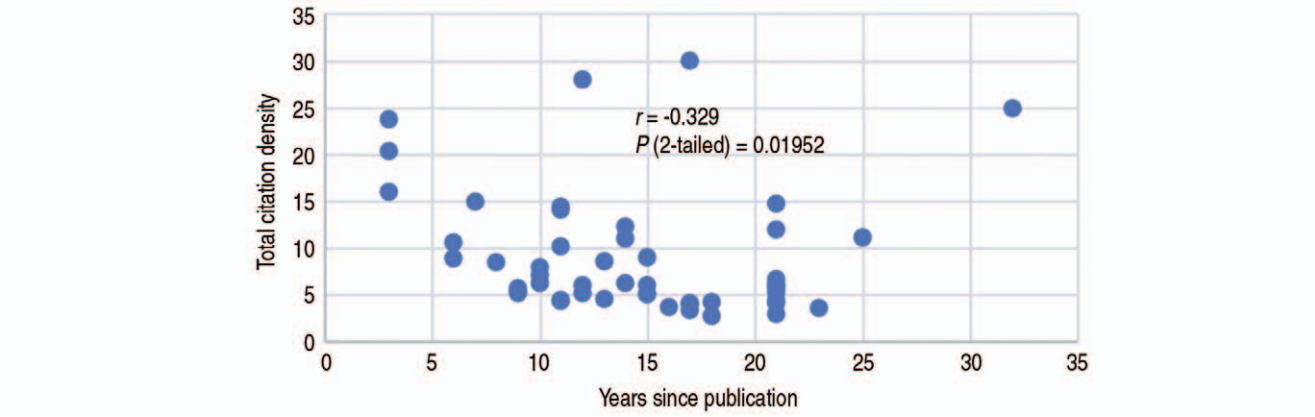

Fig. 4. Relationship of years since publication and total citation density.

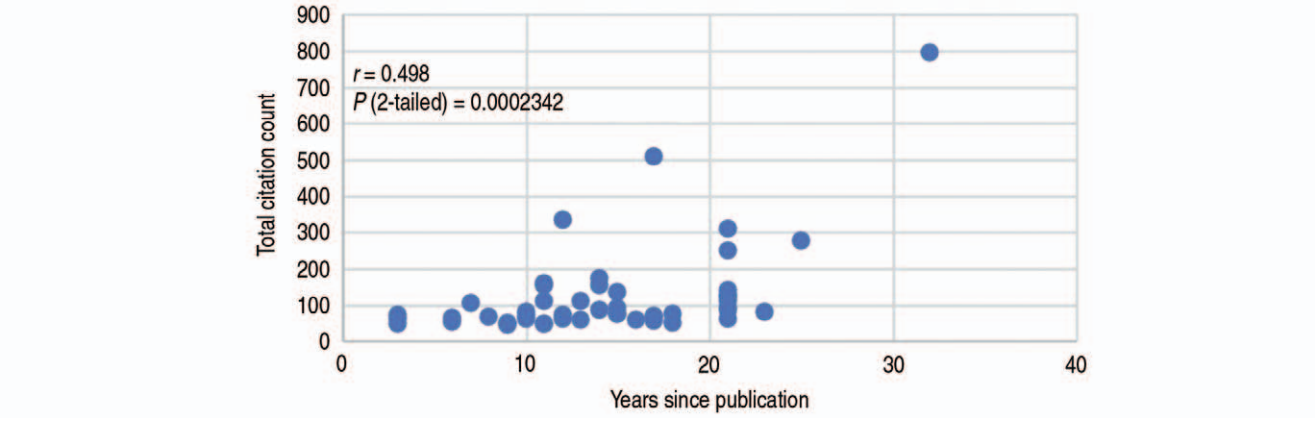

Fig. 5. Relationship of years since publication and total citation count.

Table 3. The Most Highly Cited Authors in Periacetabular Osteotomy Research

Author	No. of articles in the cohort	No. of first author appearances	Weighted citation points	Scopus h-index
Ganz, Reinhold (Berne, Switzerland)	13	2	455	79
Millis, Michael B. (Boston, MA, USA)	10	1	175	47
Kim, Young-Jo (Boston, MA, USA)	9	0	147	47
Siebenrock, Klaus A. (Berne, Switzerland)	7	3	241	52
Clohisy, John C. (St. Louis, MO, USA)	7	5	178	62
Schoenecker, Perry L. (St. Louis, MO, USA)	7	0	178	53
Trousdale, Robert T. (Rochester, MN, USA)	6	2	135	61

Considering that only five of the 50 top-cited articles were found to be level II evidence and no articles were found to be level I evidence, influential high-level evidence that is consistent with that from other areas of orthopaedics is clearly lacking in the literature on PAO[21]. The finding of this study showing strong correlation between the citation count and density indicates a continued interest and popularity of historically influential works related to PAO. This result is different from that of a foot and ankle citation analysis which found a significant discrepancy between total citations and citation density[19].

In the landmark article reported by Ganz in 1988, allowing patients to bear weight following the procedure without immobilization is attributed to the new technique using a Smith-Peterson approach that allows the posterior pillar to remain intact[9]. Out of 75 procedures, Ganz et al.[9] experienced complications including two intra articular osteotomies, one nonunion, four patients with ectopic bone formation, and one femoral nerve palsy that resolved. Despite these impressive initial results, numerous authors clearly warn of the technical demand of the technique and the steep learning curve which should be addressed through cadaveric practice[31,35]. In a follow-up study of these original patients conducted 20 years later, Steppacher et al.[24] reported a hip preservation rate of 60%, while also suggesting minor alterations to the originally presented PAO technique.

The top 50-cited articles include several examples of the development of new PAO techniques. In an effort to address the extensive exposure and asphericity of osteotomy surfaces observed in the Bernese PAO, a curved PAO technique was proposed in 2005 which sought to limit dissection, prevent outside ilium exposure, and create osteotomy surfaces with a matched curvature[46]. Use of a direct anterior approach to prevent the abductor dissection and resulting postoperative morbidity related to use of the Bernese PAO was proposed in an earlier article[43]. Development of a minimally invasive transsartorial approach PAO was recently reported[56].

There are limitations regarding this citation analysis. First, several of the analysis steps had an inherent subjective nature–such as determining levels of evidence and article exclusion from the cohort–which increases the opportunity for observer bias. Second, factors other than high citation count may adequately represent the influence of an article within a field, which means that influential articles could have been left out of this study. Techniques for considering other factors of influence were implemented–such as utilizing five-year citation density. A final consideration is that author position was not weighed in summation of overall author productivity.

CONCLUSION

This study successfully provides collection, analyses, and discussion of trends and characteristics found in the most influential PAO related literature. A large majority of articles were level of evidence IV. However, no correlation was observed between the level of evidence and increase in any of the various citation counts. Therefore, moving forward, considering techniques for increasing the motivation for PAO related studies showing a high level of evidence may be beneficial for stronger validation of specific PAO techniques. Ultimately, the presented information characterizing the most influential authors and articles related to PAO may offer guidance for authors hoping to make a substantial contribution to the PAO literature in the future.

CONFLICT OF INTEREST

Dr. Stover has stock options with Radlink, is a Depuy Synthes consultant, and receives travel costs and peridium from AO foundation/AO North America. The authors declare

that there is no potential conflict of interest relevant to this article.

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