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Research article

A bibliometric analysis and visualization of research trends on periacetabular osteotomy

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ABSTRACT

Bernese periacetabular osteotomy (PAO) is a practical and safe acetabular reorientation technique used to correct structural hip deformities, and much relevant literature has been published over the past decades. This bibliometric study aims to determine the status of PAO research between 1994 and 2022. Information about PAO research publications from 1994 to 2022 was obtained from the Web of Science Core Collection. This bibliometric study is implemented and analyzed through three bibliometric tools with respect to publication counts, countries, institutions, authors, journals, funding agencies, references and keywords. In total, 634 publications concerning PAO were identified. The United States and Washington University in St. Louis have published the most literature in terms of country and institution. Additionally, Switzerland and the University of Bern are the country and the institution with the highest average number of citations in the PAO field. The most published and co-cited journal is *Clinical Orthopaedics and Related Research*. Burst keyword detection has discovered that 'patient-reported outcome', 'instability', 'risk', 'survivorship' and 'outcome' are regarded as the current research frontier. In summary, our findings provide insight into the bibliometric overview of research status in the PAO field, which may offer later investigators' references in exploring further research directions.

INTRODUCTION

Bernese periacetabular osteotomy (PAO) is used to correct pathologic deformities of the hip joint as a practical and safe acetabular reorientation technique. It is currently recognized as an ideal hip preservation method for treating adolescent and adult hip dysplasia. The PAO procedure was originally proposed and popularized by Ganz and colleagues, enabling the preservation of the integrity of the posterior column with less disruption of the blood supply to the acetabular fragment [1–3]. The acetabular fragment can be adjusted flexibly with no obvious effect on the female birth canal through this method [4, 5]. The most common complications include transient nerve palsy, non-union and heterotopic ossification [6–8]. However, it has been widely used in hip diseases, including femoroacetabular impingement (FAI), developmental dysplasia of the hip (DDH), neurogenic acetabular dysplasia and Legg-Calve-Perthes disease (LCPD) [9–15]. Over the past few decades, the number of publications relevant to PAO has been growing and indications have been further extended with the deepening of the understanding of hip pathomorphology. Thus, it is necessary to determine the research trends and hotspots of PAO, which may promote the development of this surgical procedure.

Bibliometrics is a novel scientific study that uses statistics and visualization tools to present publishing trends and discover characteristics and relationships among existing academic publications within a certain topic [16]. In recent years, it has been extensively applied in hip orthopedics to reveal the research status of major hip diseases and surgical techniques, such as osteonecrosis of the femoral head [17], FAI [18], DDH [19] and surgical hip dislocation [20].

However, the literature on PAO has not been well-studied currently. Therefore, this study aims to clarify the global development trends and research status of PAO over the past few decades through bibliometrics. Our study may provide useful ideas and perspectives for follow-up research on this powerful technique.

MATERIALS AND METHODS

Data acquisition and retrieval strategy

The Web of Science database is an authoritative and multidisciplinary database containing many influential and high-quality academic journals worldwide. It is widely considered highly

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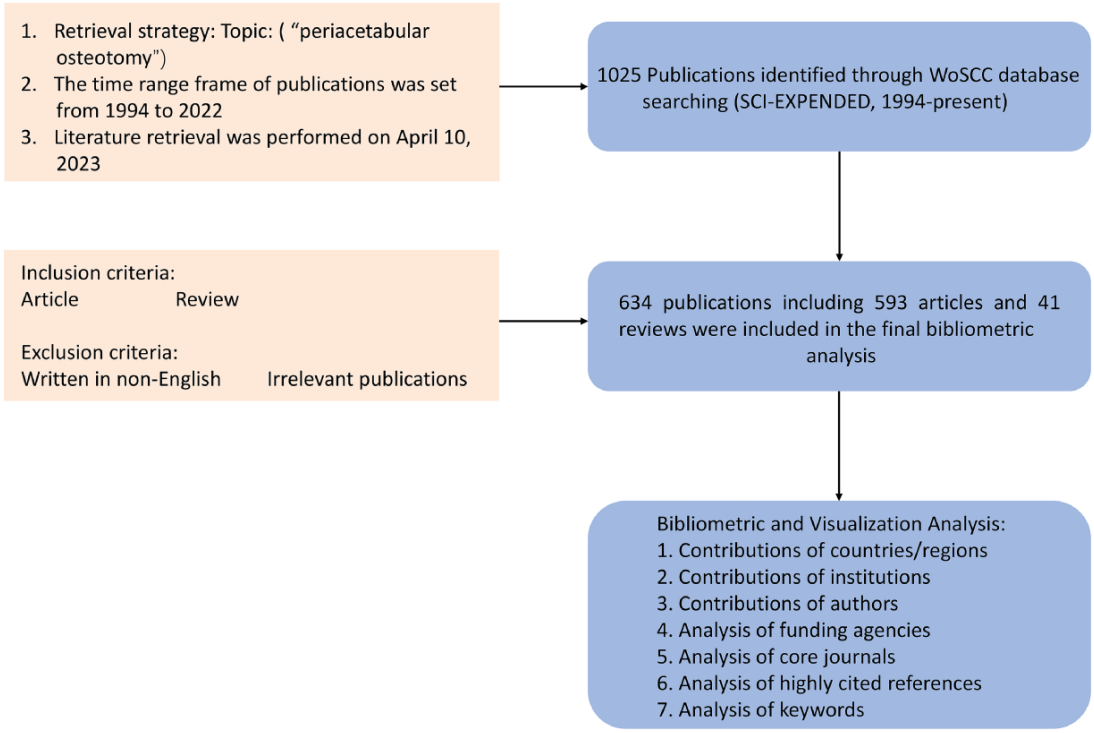

Fig. 1. Flowchart for the selection of literature included in this study.

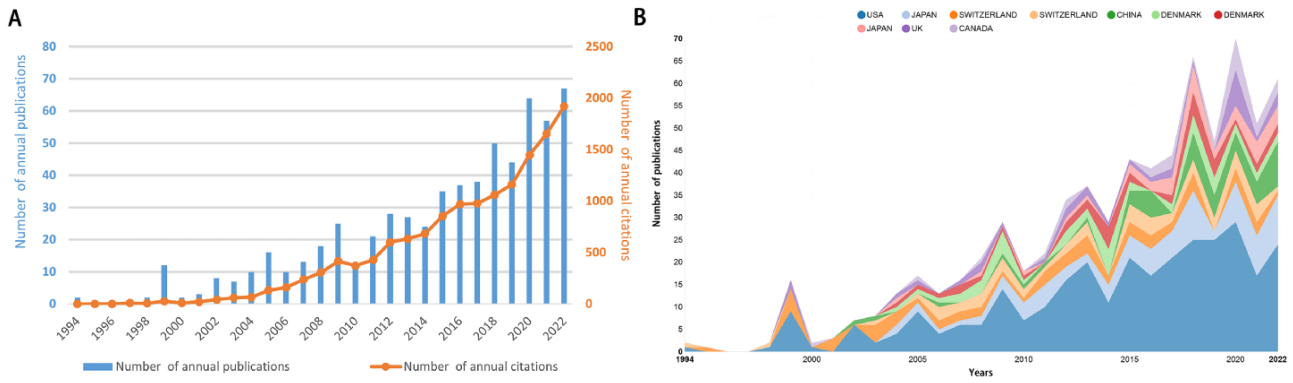

Fig. 2. (A) The number of annual publications and citations on PAO research from 1994 to 2022. (B) The annual number of publications in the top 10 most productive countries from 1994 to 2022.

dependable and optimal for bibliometric research [21, 22]. Therefore, we collected the data source of publications from the Web of Science Core Collection (WoSCC). Data retrieval and acquisition were conducted within 1 day (10 April 2023). The retrieval formula was set to Topic: (PAO). In our bibliometric study, we endeavored to select papers published between 1988 and 2022, encompassing the historical evolution of PAO. However, it should be noted that the WoSCC database did not find publications predating 1994. Thus, we chose literature from 1994 to 2022 (31 December 2022), and language was restricted to English. The literature types were limited to original articles and reviews. Figure 1 illustrates the literature retrieval and selection procedure.

Data extraction and collection

After carefully and manually excluding unrelated literature, we collected the data information of the selected literature. All included documents were downloaded and exported in text format. Information from the selected articles, including the annual number of publications, citation frequency, titles, authors, affiliations, countries, keywords, journals, publication year, references, funding agencies, average citation per item (ACI) and *H*-index, was obtained. The *H*-index is a broad measure of the impact of researchers, institutions or countries based on their scientific contributions. Microsoft Office Excel 2019 was used for data entry and management.

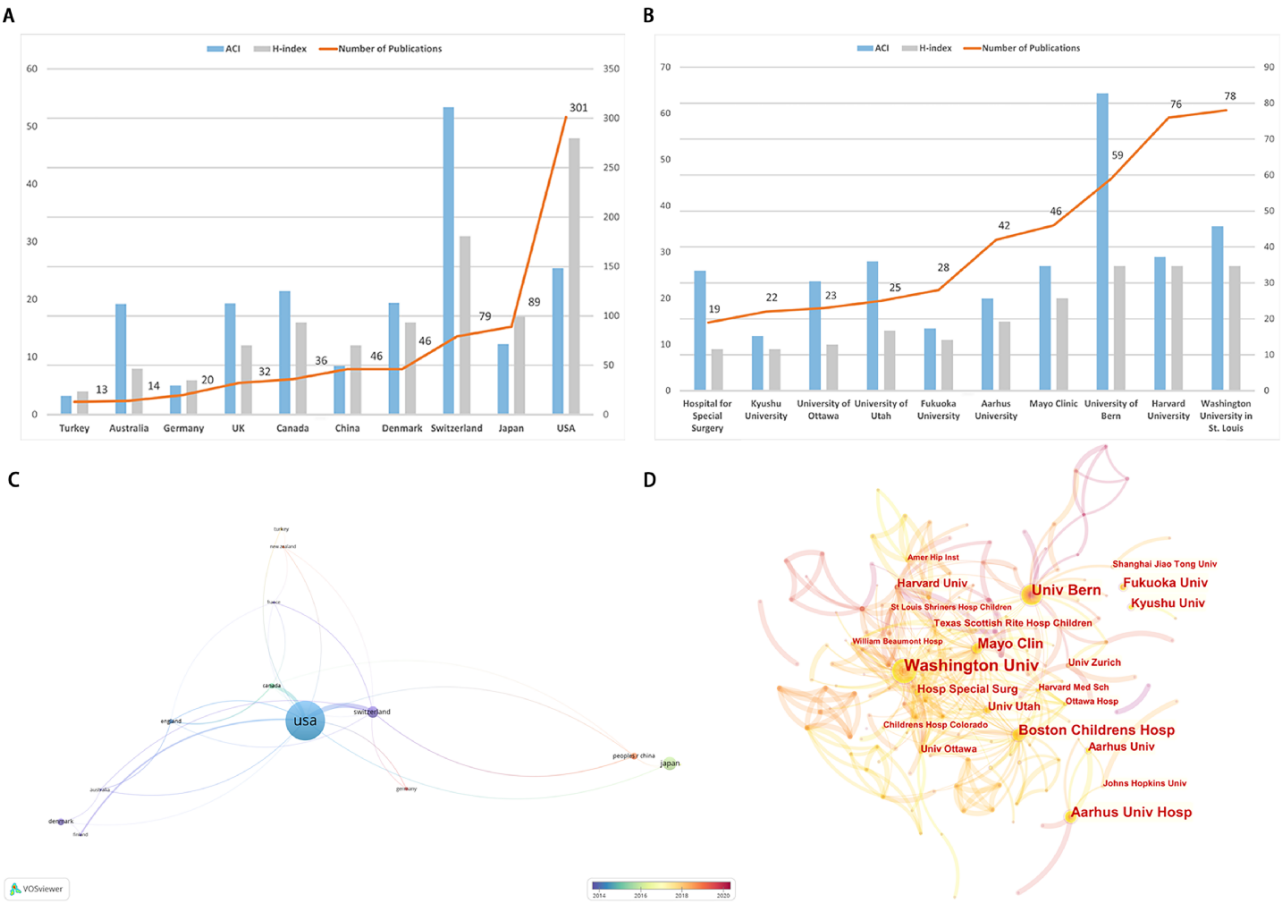

Fig. 3. (A) The top 10 countries with the most publications related to PAO research. (B) The top 10 institutions with the most publications related to PAO research. (C) The co-authorship map of countries/regions involved in PAO research (generated using VOSviewer). (D) The cooperation network map of institutions involved in PAO research (generated using CiteSpace).

Bibliometric and visualized analysis

In this study, we employed the following three bibliometric tools: VOSviewer (Version 1.6.18) [23], CiteSpace V (Version 5.7. R2) [24] and an online analytical platform (https://bibliometric.com/). We used the default parameters in CiteSpace and VOSviewer. Default parameter settings for VOSviewer are as follows: visualization (scale: 1.0), labels (size variation: 0.5, max. length: 30) and lines (size variation: 0.5, minimum strength: 0, maximum lines: 1000). For CiteSpace, the parameter settings include selection criteria (g-index: $k = 25$), look-back years (5), time span (1994–2022) and years per slice (1). VOSviewer was utilized to visualize the results related to the co-authorship of countries, the co-citation of journals and keyword co-occurrences. The size of the nodes reflected the number of publications, citations or co-occurrences. The connections between the nodes represented the associations, including co-authorship or co-citation. Total link strength (TLS) represented the strength of the lines between the observed nodes.

CiteSpace was applied to construct cooperation networks of institutions or authors, and we also conducted the burst analysis of keywords and co-cited references by using CiteSpace. Betweenness centrality is a key parameter of centrality that could evaluate the scientific importance of the nodes in a network. In terms of the clusters view map, cited authors with similar attributes were aggregated into a cluster. The bursts of keywords are usually used to present the evolution of research hotspots and detect intuitively new development trends in the field. Through bibliometric analysis of CiteSpace, we have selected the top 20 keywords and references with the strongest citation bursts.

RESULTS

Global publication and citation trend

Among the 1025 initial publications, a total of 634 qualified publications (593 articles and 41 reviews) were identified in this study (Fig. 1). The development trends in the number of annual publications and citations over the past few decades are illustrated in Fig. 2A. Despite occasional fluctuations leading to decreases sometimes, the overall contributions of publications and citations on PAO showed an ascending annual trend worldwide and reached its peak in 2022 with a total of 67 papers and 1920 citations. The contributions of global publications increased by 3250% from 1994 to 2022, and almost 44.5% of them (282 papers) were published in the last 5 years.

Contributions of countries/regions

The change in the annual publication numbers of the top 10 prolific countries from 1994 to 2022 is shown in Fig. 2B. The 634 publications on PAO were contributed by 38 countries/regions in total, and the top 10 most prolific countries are presented in Fig. 3A. The United States produced the largest number of documents, with 301 articles published (47.5%), followed by Japan (89, 14.0%) and Switzerland (79, 12.5%). The United States also had the highest *H*-index (*H*-index = 48), followed by Switzerland (*H*-index = 31) and Japan (*H*-index = 17). Switzerland had the highest average number of citations (53.34), followed by the United States (25.44) and Canada (21.50). The collaboration network map among global countries/regions is displayed visually in Fig. 3C. We found that the United States had the closest cooperation with Switzerland and Canada, and the top three countries with the largest TLS were the United States, Switzerland, and Canada, respectively.

Contributions of institutions

The top 10 contributing institutions are specifically displayed in Fig. 3B. Of these, five were American institutions and two were Japanese institutions. Washington University in St. Louis holds the most publications, followed by Harvard University and the University of Bern. The ACI of 64.37 in the University of Bern exceeded other institutions, ranking first. In terms of *H*-index, Washington University, Harvard University and the University of Bern were all ranked first with the *H*-index of 27. The collaborative network map of institutions was constructed by CiteSpace and is displayed in Fig. 3D. Washington University (0.08), Boston Children's Hospital affiliated with Harvard

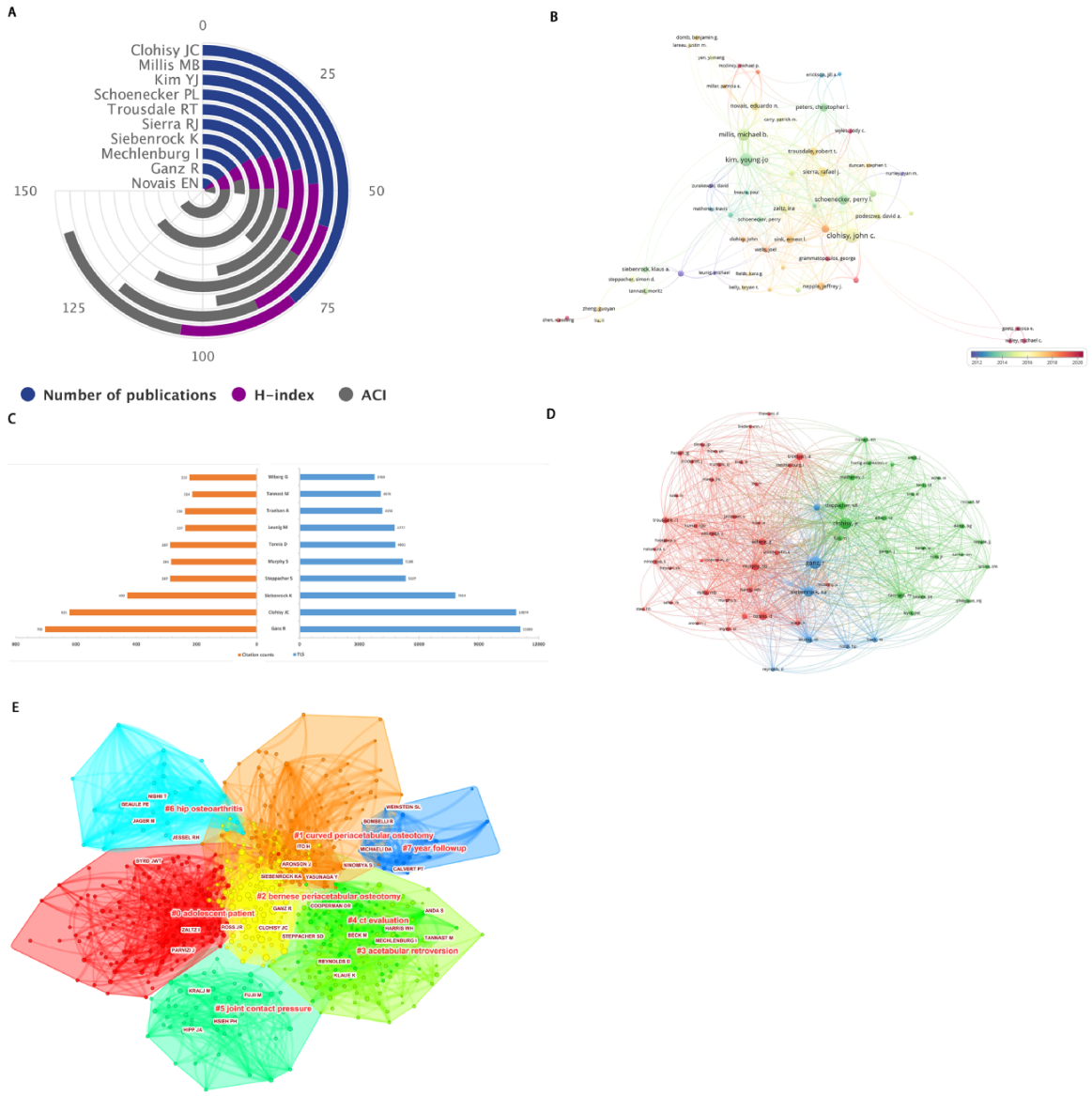

Fig. 4. (A) The top 10 most productive authors in PAO research. (B) Author co-authorship overlays the visualization map generated using VOSviewer. (C) The citation counts and TLS of the top 10 most co-cited authors. (D) Network visualization map of author co-citation analysis generated using the VOSviewer. (E) In the cluster map, cited authors with similar categories were gathered in a cluster.

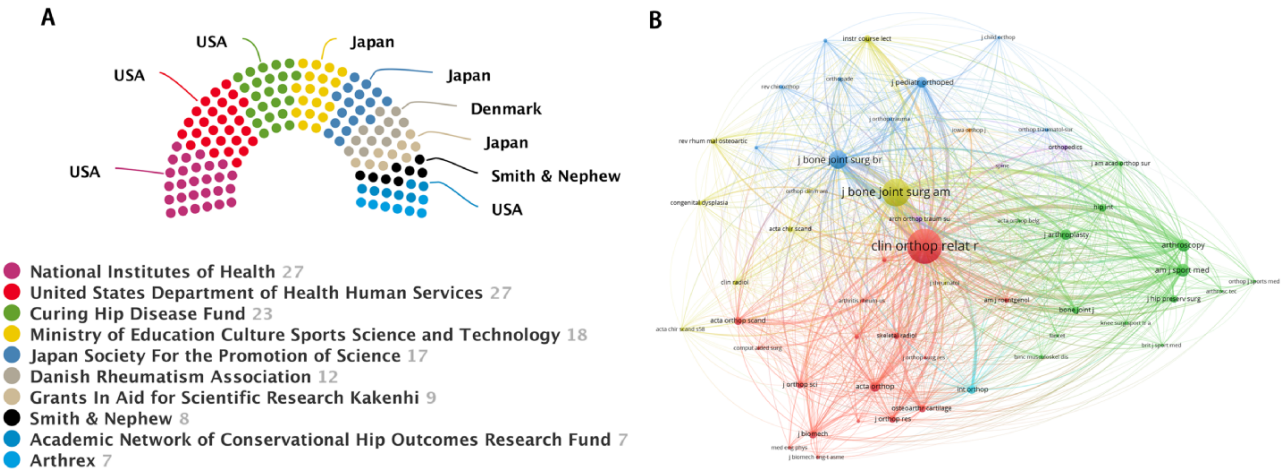

Fig. 5. (A) Top 10 related funding agencies for the support of PAO research. (B) Journal co-citation analysis by using VOSviewer.

University (0.08) and the University of Bern (0.07) were the top three institutions in terms of centrality. But none of the institutions has a centrality > 0.1. This suggests that there are a limited collaboration and communication among institutions, which could significantly impede progress in research within this field.

Contributions of authors

The top 10 contributing authors who had the most active productivity are listed in Fig. 4A. Clohisy JC was the author with the most papers, totaling 78, followed by Millis MB, Kim YJ, Schoenecker PL and Trousdale RT. Figure 4B shows an overlay visualization map for author co-authorship analysis with a minimum of five publications. In the network map, Clohisy JC, Kim YJ and Millis MB were situated at the central positions within the cooperating clusters with the largest TLS. Based on the co-citation analysis performed with VOSviewer (Fig. 4D), we defined a 'core author' as the one who had obtained at least 50 citations. The top three influential authors with the largest TLS were Ganz R, Clohisy JC and Siebenrock K. The co-citation counts and TLS of the top 10 most co-cited authors are displayed in Fig. 4C. Meanwhile, the co-citation relationships between authors were visualized by CiteSpace through the construction of network cluster maps. Regarding the cluster view of the co-citation map (Fig. 4E), the weighted mean silhouette value of clusters #0 to #7 was 0.764, indicating good homogeneity. Research categories of authors were classified into eight clusters, including 'adolescent patient' (#0), 'curved PAO' (#1), 'Bernese PAO' (#2), 'acetabular retroversion' (#3), 'computed tomography evaluation' (#4), 'joint contact pressure' (#5), 'hip osteoarthritis' (#6) and 'year follow-up' (#7), intuitively presenting the intellectual concerns in current research area of PAO.

Analysis of funding agencies

Both the National Institutes of Health and the US Department of Health and Human Services funded the most publications (27; 4.3%), followed by the Curing Hip Disease Fund (23; 3.6%) and the Ministry of Education, Culture, Sports, Science and Technology (18; 2.8%) (Fig. 5A). Of the top 10 funding agencies, four funding organizations were located in the United States and three were from Japan. The rest were from Denmark, Smith and Nephew and Arthrex, respectively.

Analysis of core journals

The top 10 fruitful journals altogether published 391 papers on PAO, accounting for 61.7% of all 634 documents. Table I summarizes the information on the top 10 journals. Among these, *Clinical Orthopaedics and Related Research* (112, 17.7%) published the most literature, followed by *Journal of Hip Preservation Surgery* (60, 9.5%) and *Journal of Bone* and *Joint Surgery-American Volume* (57, 9.0%). According to the Journal Citation Reports (JCR) 2020 standards, the top 10 most productive journals were classified as Q1 in 6, Q2 in 1 and Q3 in 3. VOSviewer software was used to visualize the co-citation of journals. As displayed in Fig. 5B, 54 journals with a minimum of 40 citations were included. The top three journals with the largest TLS are listed as follows: *Clinical Orthopaedics and Related Research, Journal of Bone, Joint Surgery-American Volume* and *Journal of Bone and Joint Surgery-British Volume*.

Analysis of high cited references

Table II presents the top 10 most impactful papers. The highest and lowest cited times of these papers were 459 and 176, respectively. Among these highly cited papers, six were from Switzerland and four were from the United States. These articles were issued between 1995 and 2015, and all of them obtained more than 170 citation counts. Figure 6 presents the top 20 references with the strongest citation bursts. In this map, the time interval and the corresponding period are shown when the reference burst occurred. Among them, the article with the strongest burst value was published by Lerch et al. [25], followed by Steppacher et al. [26] and Albers et al. [27]. Interestingly, all three studies investigated the clinical outcomes of patients treated with PAO at an average follow-up of 30, 20 and 10 years, respectively. It is also worth noting that the top seven references with the strongest

Table I. ***The top 10 journals with the most publications in PAO research***

Rank	*Journal title*	*Counts*	*Percentage (N/634)*	*Impact Factor (2021)*	*JCR(2021)*	*H-index*	*ACI*
1	*Clinical Orthopedics and Related Research*	112	17.7	4.837	Q1	41	49.11
2	*Journal of Hip Preservation Surgery*	60	9.5	1.604	Q3	9	5.27
3	*Journal of Bone and Joint Surgery-American Volume*	57	9	6.558	Q1	29	57.68
4	*Hip International*	32	5	1.756	Q3	9	7.44
5	*International Orthopaedics*	27	4.3	3.479	Q2	11	14.78
6	*American Journal of Sports Medicine*	23	3.6	7.01	Q1	13	29.48
7	*Journal of Arthroplasty*	22	3.5	4.435	Q1	10	13.36
8	*Acta Orthopaedica*	20	3.2	3.925	Q1	14	32.7
9	*Bone & Joint Journal*	20	3.2	5.385	Q1	13	18.15
10	*Journal of Pediatric Orthopaedics*	18	2.8	2.537	Q3	7	9.83

Table II. ***The top 10 most cited works of literature in PAO research***

Rank	*Article title*	*Citations*	*Author*	*Journal title*	*Year*
1	Anterior femoro-acetabular impingement due to acetabular retroversion—Treatment with periacetabular osteotomy	459	Siebenrock, KA	*Journal of Bone and Joint Surgery-American Volume*	2003
2	Mean 20 year followup of bernese periacetabular osteotomy	391	Steppacher, SD	*Clinical Orthopedics and Related Research*	2008
3	Anterior femoroacetabular impingement Part I. Techniques of joint preserving surgery	341	Lavigne, M	*Clinical Orthopedics and Related Research*	2004
4	Anterior femoroacetabular impingement after periacetabular osteotomy	299	Myers, SR	*Clinical Orthopedics and Related Research*	1999
5	Periacetabular and intertrochanteric osteotomy for the treatment of osteoarthrosis in dysplastic hips	251	Trousdale RT	*Journal of Bone and Joint Surgery-American Volume*	1995
6	Periacetabular osteotomy: a systematic literature review	203	Clohisy, JC	*Clinical Orthopedics and Related Research*	2009
7	Bernese periacetabular osteotomy	200	Siebenrock, KA	*Clinical Orthopedics and Related Research*	1999
8	What are the radiographic reference values for acetabular under- and overcoverage?	199	Tannast, M	*Clinical Orthopedics and Related Research*	2015
9	Intermediate to long-term results following the Bernese periacetabular osteotomy and predictors of clinical outcome	180	Matheney, T	*Journal of Bone and Joint Surgery-American Volume*	2009
10	Descriptive epidemiology of femoroacetabular impingement a North American cohort of patients undergoing surgery	176	Clohisy, JC	*American Journal of Sports Medicine*	2013

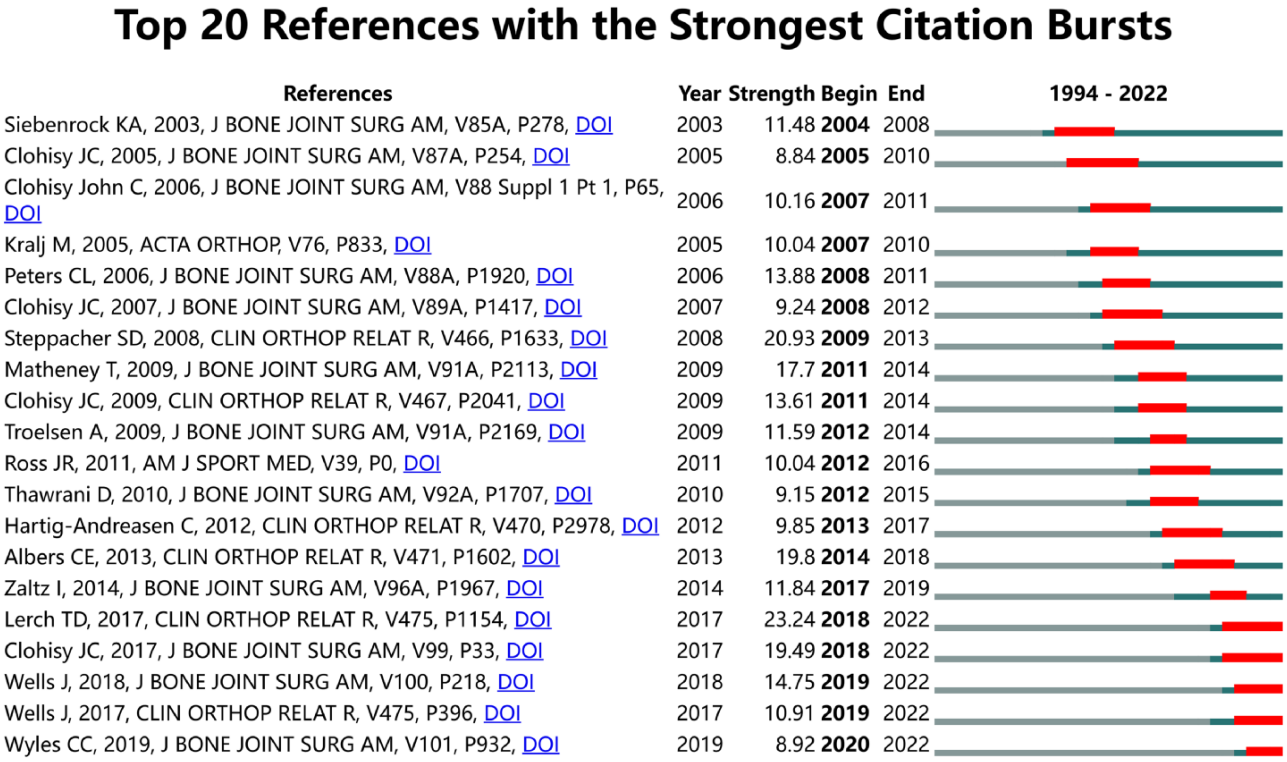

Fig. 6. The top 20 references with the strongest citation bursts from 1994 to 2022 (generated using CiteSpace).

burst value all focused on the survival and clinical outcomes of patients after PAO surgery [25–31], which demonstrates the potential importance of the topic.

Keyword analysis of research hotspots

A total of 1300 keywords were extracted from all included documents. Additionally, we have presented an overlay visualization map of co-occurrence keywords through VOSviewer (Fig. 7A). Different colors were used for each keyword depending on their average appearance year in publications. Keywords such as instability, outcome and survivorship have attracted special attention recently, which suggests that these topics may continue to be the hotspots in the field of PAO research.

Furthermore, we identified keywords for PAO research using two dimensions: the burst strength and the burst time. Figure 7B displays the top 20 keywords with the strongest citation bursts from 1994 to 2022. The principal research hotspots include dysplastic hip, retroversion, Bernese PAO, risk and survivorship. Among the entire list with the strongest citation bursts, 'retroversion', 'innominate osteotomy', 'osteoarthrosis' and 'replacement' were the top four keywords with the strongest burst strength (11.06, 7.94, 7.04 and 6.36, respectively). Notably, we also found that the citation burst time of keywords, including 'patient-reported outcome', 'instability', 'risk', 'survivorship' and 'outcome', has continued to 2022 and the bursts are still ongoing, which indicates that more focus needs to be placed on these research topics.

DISCUSSION

In this study, we attempted to provide an elaborate and macroscopic overview of the publication status, research hotspots and prevailing tendencies regarding PAO research based on bibliometric analysis. The increasing number of publications and citations in the field of PAO reflects the growing importance of this surgical technique in addressing a range of hip pathologies. The United States and Switzerland have established a world-leading position in this field. Our results indicated that Professors Ganz R, Clohisy JC, Millis MB, Kim YJ and Siebenrock K have made outstanding contributions to this field. For instance, Professor Ganz R from the University of Bern pioneered and popularized the PAO procedure [1]. Professor Clohisy JC from Washington University has provided a detailed and systematic overview of the theoretical and clinical aspects of hip disease and the PAO procedure in young adults [30, 32–34]. Professors Millis MB and Kim YJ at Harvard University explored the mechanisms of hip disorders and conducted a large number of high-quality clinical studies on PAO [11, 35–37]. As for Professor Siebenrock K from the University of Bern, he mainly devoted himself to clinical practice regarding the PAO treatment of acetabular retroversion and hip dysplasia and observed the long-term postoperative follow-up results [10, 12, 38, 39]. Currently, PAO remains a preferred non-arthroplasty method to address symptomatic adult patients with hip dysplasia [40, 41].

Overall, clinical outcomes show that PAO is an effective and safe procedure that improves pain, activity levels and hip joint function in hip dysplasia, FAI, acetabular retroversion,

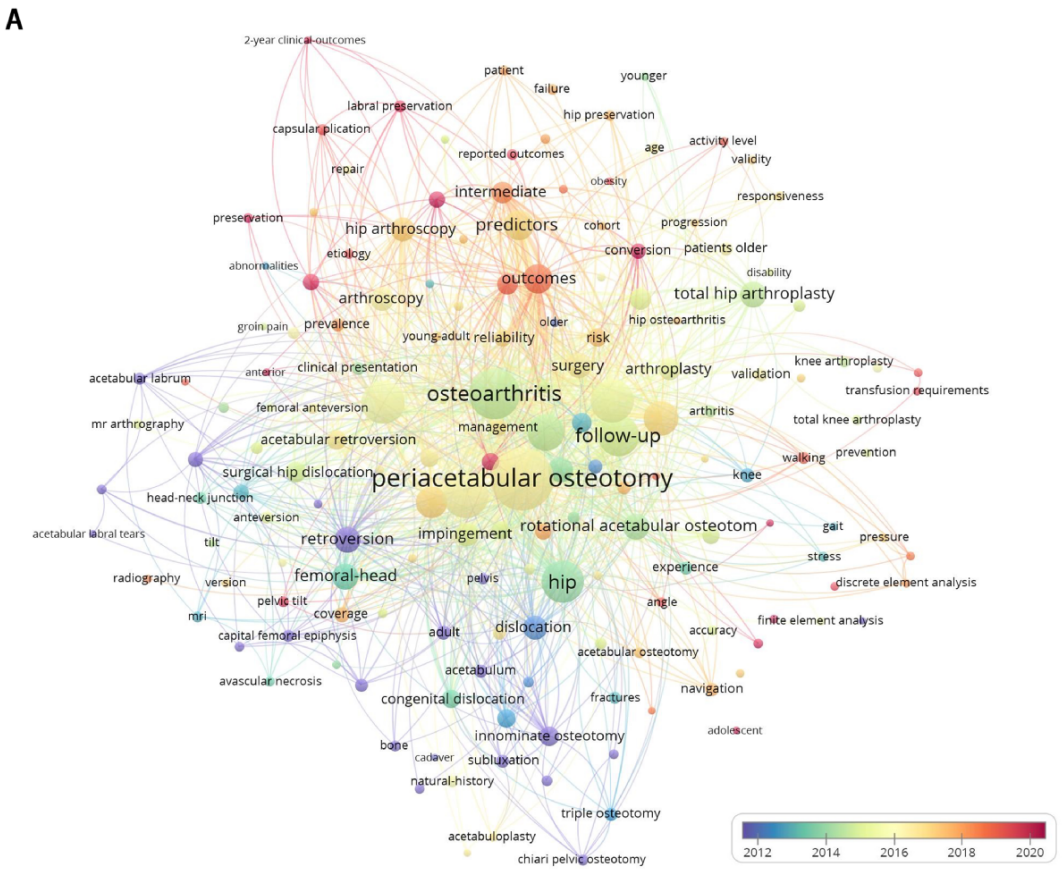

Fig. 7. (A) The overlay visualization map of the keywords co-occurrence analysis using VOSviewer. (B) The top 20 keywords with the strongest citation bursts from 1994 to 2022 (generated using CiteSpace).

anterior overcoverage and LCPD [10, 12, 14, 15, 42, 43]. In the United Kingdom, PAO surgery has been reported to significantly improve patient-reported outcome scores for DDH and FAI patients, which is sustained for up to 2 years postoperatively [44]. One study showed an average hip survival rate of 92% during an average follow-up period of 15 years after PAO treatment for symptomatic acetabular dysplasia, and another study demonstrated that over 75% of the hips were retained 18 years postoperatively [31, 37]. As for complications, the risk of complications following PAO was associated with hypermobility, older age, oversized Body Mass Index, moderate-to-severe dysplasia and more medial osteotomy location [45, 46]. A long-term follow-up study found that increasing age and the presence of preoperative osteoarthritis were regarded as risk factors for composite failure of hip dysplasia treated with PAO [47]. Another multicenter study investigated the incidence of complications related to PAO and reported a 5.9% risk of major complications beyond the learning curve [6]. However, PAO has few complications and a low risk of permanent disability at an average follow-up of 10 years for experienced surgeons [7]. There are no cases of infection, non-union, heterotopic ossification or nerve palsy in a prospective series using the modified Stoppa approach [48].

Many clinicians have been optimizing the surgical approach and details of PAO by applying new methods and techniques such as computer-assisted navigation and 3D-printed osteotomy guides [48–54]. Although PAO has been researched extensively and has shown positive outcomes, there are still several areas within the field that could benefit from further investigation. First, further biomechanical research and gait analysis on the PAO procedure are necessary to delve into its impact on joint load distribution and stability and to explore optimal joint stress contact areas and joint congruency. Second, optimized postoperative rehabilitation programs are worth further investigation, especially for some comorbid patients with diabetes, osteoporosis or sarcopenia, to accelerate patient recovery. Lastly, conducting more comparative studies regarding cost-effectiveness or long-term effects between PAO and other treatment options, as well as exploring minimally invasive variations of the PAO procedure, could provide valuable insights for personalized treatment approaches.

To our knowledge, this is the first bibliometric study to date to comprehensively analyze publications in the PAO field over the widest range of time horizons. By synthesizing and visualizing bibliographic data, this study provides valuable insights into the global landscape of PAO research, showcasing its growth trajectory, prominent contributors, research hotspots and emerging trends. The study's significance lies in its ability to guide future researchers and clinicians by identifying areas of high interest, potential collaboration opportunities and critical research gaps, thus advancing PAO research in the coming years.

LIMITATIONS

Undeniably, this work still has several limitations. First, we exclusively relied on the WoSCC database for literature identification, neglecting other medical databases. Although the utilization of additional biomedical databases may not significantly increase the yield of relevant publications, it could potentially result in the omission of some important studies. Second, we did not include research published in non-English language journals, which may have resulted in an incomplete analysis and potential language bias. Third, our study's timeframe, up to 2022, might overlook recent developments that could impact the field. Fourth, our study only reflects the current status and trend of PAO due to its time-varying characteristics. Additionally, this bibliometric analysis relies mainly on algorithmically generated results, which are somewhat lacking in human induction. Due to algorithmic limitations and biases, some valuable research is inevitably overlooked, potentially affecting the accuracy of the results to some extent.

CONCLUSION

This study demonstrated a historical and macroscopic overview of the research hotspots and the worldwide trends in PAO publications between 1994 and 2022. Over the last few decades, the volume of literature involved in PAO research has shown an overall increasing trend worldwide. The United States and Switzerland are the most influential countries in this field. Articular instability, clinical survivorship, risks and patient-reported outcomes have been the most popular research topics in the field of PAO in recent years and deserve more attention. This study may provide useful ideas and perspectives for follow-up research on this powerful technique and help to further extend possible directions.

DATA AVAILABILITY

The data underlying this article will be shared on reasonable request to the corresponding author.

ACKNOWLEDGEMENTS

None declared.

CONFLICT OF INTEREST STATEMENT

None declared.

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REFERENCES

1. Ganz R, Klaue K, Vinh TS *et al.* A new periacetabular osteotomy for the treatment of hip dysplasias. Technique and preliminary results. *Clin Orthop Relat Res* 1988; **232**: 26–36.
2. Ahmad SS, Haertlé M, Konrads C *et al.* The scientific evolution of periacetabular osteotomy: a global review. *J Clin Med* 2022; **11**: 6099.

3. Tibor LM, Sink EL. Periacetabular osteotomy for hip preservation. *Ortho Clin North Am* 2012; **43**: 343–57.
4. Flückiger G, Eggli S, Kosina J *et al.* Birth after peri-acetabular osteotomy. *Der Orthopade* 2000; **29**: 63–7.
5. Lerch TD, Steppacher SD, Liechti EF *et al.* Bernese periacetabular osteotomy. Indications, technique and results 30 years after the first description. *Der Orthopade* 2016; **45**: 687–94.
6. Zaltz I, Baca G, Kim YJ *et al.* Complications associated with the periacetabular osteotomy: a prospective multicenter study. *J Bone Joint Surg Am* 2014; **96**: 1967–74.
7. Wells J, Schoenecker P, Petrie J *et al.* Are complications after the bernese periacetabular osteotomy associated with subsequent outcomes scores? *Clin Orthop Relat Res* 2019; **477**: 1157–63.
8. Selberg CM, Davila-Parrilla AD, Williams KA *et al.* What proportion of patients undergoing bernese periacetabular osteotomy experience nonunion, and what factors are associated with nonunion? *Clin Orthop Relat Res* 2020; **478**: 1648–56.
9. MacDonald SJ, Hersche O, Ganz R. Periacetabular osteotomy in the treatment of neurogenic acetabular dysplasia. *J Bone Joint Surg Br* 1999; **81**: 975–8.
10. Siebenrock KA, Schoeniger R, Ganz R. Anterior femoro-acetabular impingement due to acetabular retroversion. Treatment with periacetabular osteotomy. *J Bone Joint Surg Am* 2003; **85**: 278–86.
11. Millis MB, Kain M, Sierra R *et al.* Periacetabular osteotomy for acetabular dysplasia in patients older than 40 years: a preliminary study. *Clin Orthop Relat Res* 2009; **467**: 2228–34.
12. Siebenrock KA, Schaller C, Tannast M *et al.* Anteverting periacetabular osteotomy for symptomatic acetabular retroversion: results at ten years. *J Bone Joint Surg Am* 2014; **96**: 1785–92.
13. Georgiadis AG, Dutt V, Truong WH *et al.* Anteverting Bernese periacetabular osteotomy in the treatment of neurogenic hip dysplasia in cerebral palsy. *J Pediatr Orthop B* 2018; **27**: 473–8.
14. Nepple JJ, Freiman S, Pashos G *et al.* Combined surgical dislocation and periacetabular osteotomy for complex residual Legg-Calvé-Perthes deformities: intermediate-term outcomes. *J Bone Joint Surg Am* 2022; **104**: 780–9.
15. Nepple JJ, Parilla FW, Pashos GE *et al.* Outcomes of periacetabular osteotomy for borderline acetabular dysplasia. *J Bone Joint Surg Am* 2023; **105**: 137–44.
16. Ninkov A, Frank JR, Maggio LA. Bibliometrics: methods for studying academic publishing. *Perspect Med Educ* 2022; **11**: 173–6.
17. Wu H, Cheng K, Tong L *et al.* Knowledge structure and emerging trends on osteonecrosis of the femoral head: a bibliometric and visualized study. *J Orthop Surg Res* 2022; **17**: 194.
18. Tang F, Dai WB, Li XL *et al.* Publication trends and hot spots in femoroacetabular impingement research: a 20-year bibliometric analysis. *J Arthroplasty* 2021; **36**: 2698–707.
19. Wu H, Wang Y, Tong L *et al.* The global research trends and hotspots on developmental dysplasia of the hip: a bibliometric and visualized study. *Front Surg* 2021; **8**: 671403.
20. Peng P, Wei T, Fang W *et al.* A bibliometric analysis and visualization of research trends on surgical hip dislocation. *J Hip Preserv Surg* 2022; **10**: 8–16.
21. Martín-Martín A, Thelwall M, Orduna-Malea E *et al.* Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. *Scientometrics* 2021; **126**: 871–906.
22. Aggarwal A, Lewison G, Idir S *et al.* The State of Lung Cancer Research: a global analysis. *J Thorac Oncol* 2016; **11**: 1040–50.
23. van Eck NJ, Waltman L, van Eck NJ. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 2010; **84**: 523–38.
24. Synnestvedt MB, Chen C, Holmes JH. CiteSpace II: visualization and knowledge discovery in bibliographic databases. *AMIA Annu Symp Proc* 2005; **2005**: 724–8.
25. Lerch TD, Steppacher SD, Liechti EF *et al.* One-third of hips after periacetabular osteotomy survive 30 years with good clinical results, no progression of arthritis, or conversion to THA. *Clin Orthop Relat Res* 2017; **475**: 1154–68.
26. Steppacher SD, Tannast M, Ganz R *et al.* Mean 20-year followup of Bernese periacetabular osteotomy. *Clin Orthop Relat Res* 2008; **466**: 1633–44.
27. Albers CE, Steppacher SD, Ganz R *et al.* Impingement adversely affects 10-year survivorship after periacetabular osteotomy for DDH. *Clin Orthop Relat Res* 2013; **471**: 1602–14.
28. Peters CL, Erickson JA, Hines JL. Early results of the Bernese periacetabular osteotomy: the learning curve at an academic medical center. *J Bone Joint Surg Am* 2006; **88**: 1920–6.
29. Matheney T, Kim YJ, Zurakowski D *et al.* Intermediate to long-term results following the Bernese periacetabular osteotomy and predictors of clinical outcome. *J Bone Joint Surg Am* 2009; **91**: 2113–23.
30. Clohisy JC, Ackerman J, Baca G *et al.* Patient-reported outcomes of periacetabular osteotomy from the prospective ANCHOR cohort study. *J Bone Joint Surg Am* 2017; **99**: 33–41.
31. Wells J, Schoenecker P, Duncan S *et al.* Intermediate-term hip survivorship and patient-reported outcomes of periacetabular osteotomy: the Washington University experience. *J Bone Joint Surg Am* 2018; **100**: 218–25.
32. Clohisy JC, Beaulé PE, O'Malley A *et al.* AOA symposium. Hip disease in the young adult: current concepts of etiology and surgical treatment. *J Bone Joint Surg Am* 2008; **90**: 2267–81.
33. Clohisy JC, Schutz AL, St John L *et al.* Periacetabular osteotomy: a systematic literature review. *Clin Orthop Relat Res* 2009; **467**: 2041–52.
34. Clohisy JC, Nepple JJ, Larson CM *et al.* Persistent structural disease is the most common cause of repeat hip preservation surgery. *Clin Orthop Relat Res* 2013; **471**: 3788–94.
35. Millis MB, Kim YJ. Rationale of osteotomy and related procedures for hip preservation: a review. *Clin Orthop Relat Res* 2002; **405**: 108–21.
36. Espinosa N, Strassberg J, Belzile EL *et al.* Extraarticular fractures after periacetabular osteotomy. *Clin Orthop Relat Res* 2008; **466**: 1645–51.
37. Millis MB, McClincy M. Periacetabular osteotomy to treat residual dysplasia in adolescents and young adults: indications, complications, results. *J Child Orthop* 2018; **12**: 349–57.
38. Siebenrock KA, Schöll E, Lottenbach M *et al.* Bernese periacetabular osteotomy. *Clin Orthop Relat Res* 1999; **363**: 9–20.
39. Siebenrock KA, Steppacher SD, Albers CE *et al.* Diagnosis and management of developmental dysplasia of the hip from triradiate closure through young adulthood. *J Bone Joint Surg Am* 2013; **95**: 748–55.
40. Murphy SB, Millis MB, Hall JE. Surgical correction of acetabular dysplasia in the adult. A Boston experience. *Clin Orthop Relat Res* 1999; **363**: 38–44.
41. Shibata KR, Matsuda S, Safran MR. Open treatment of dysplasia-other than PAO: does it have to be a PAO? *J Hip Preserv Surg* 2017; **4**: 131–44.
42. Okoroafor UC, Pascual-Garrido C, Schwabe MT *et al.* Activity level maintenance at midterm follow-up among active patients undergoing periacetabular osteotomy. *Am J Sports Med* 2019; **47**: 3455–9.
43. Petrie JR, Novais EN, An TW *et al.* What is the impact of periacetabular osteotomy surgery on patient function and activity levels? *J Arthroplasty* 2020; **35**: S113–s18.
44. Holleyman R, Sohatee MA, Witt J *et al.* Periacetabular osteotomy for developmental dysplasia of the hip and femoroacetabular impingement: a study using the U.K. Non-Arthroplasty Hip Registry (NAHR) data set. *J Bone Joint Surg Am* 2020; **102**: 1312–20.
45. Salih S, Groen F, Hossein F *et al.* Hypermobility, age 40 years or older and BMI >30 kg m^{-2} increase the risk of complications following periacetabular osteotomy. *J Hip Preserv Surg* 2020; **7**: 511–7.
46. Sivamurugan G, Westermann RW, Glass N *et al.* Incidence and risk factors for non-union of the superior ramus osteotomy when hip dysplasia is treated with periacetabular osteotomy. *J Hip Preserv Surg* 2023; 1–7.
47. Willey MC, Westermann RW, Glass N *et al.* Risk factors for composite failure of hip dysplasia treated with periacetabular osteotomy: a minimum 10-year follow-up. *J Am Acad Orthop Surg* 2022; **30**: e690–702.

48. Baraka MM, Sallam HE, Abdelwahab MM. Periacetabular osteotomy: a novel application of modified Stoppa approach. *Sicot-j* 2022; **8**: 33.
49. Murphy SB, Millis MB. Periacetabular osteotomy without abductor dissection using direct anterior exposure. *Clin Orthop Relat Res* 1999; **364**: 92–8.
50. Wang X, Liu S, Peng J *et al.* Development of a novel customized cutting and rotating template for Bernese periacetabular osteotomy. *J Orthop Surg Res* 2019; **14**: 217.
51. Brumat P, Mihalič R, Benulič Č *et al.* Patient-specific template and electromagnetic navigation assisted bilateral periacetabular osteotomy for staged correction of bilateral injury-induced hip dysplasia: a case report. *J Hip Preserv Surg* 2021; **8**: 192–6.
52. Shelton TJ, Monazzam S, Calafi A *et al.* Preoperative 3D modeling and printing for guiding periacetabular osteotomy. *J Pediatr Orthop* 2021; **41**: 149–58.
53. Ma S, Xiao L, Guo D *et al.* Application of 3D-printed osteotomy guides in periacetabular osteotomy: a short-term clinical study. *Int J Artif Organs* 2022; **45**: 945–51.
54. Naito M, Shiramizu K, Akiyoshi Y *et al.* Curved periacetabular osteotomy for treatment of dysplastic hip. *Clin Orthop Relat Res* 2005; **433**: 129–35.