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A systematic review of retractions in biomedical research publications: reasons for retractions and their citations in Indian affiliations

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Retractions of peer-reviewed biomedical journal articles with Indian authorship have been on the rise for many years. Our study aimed to investigate the reason behind these retractions, namely plagiarism, falsification, fabrication, duplicate publication, author conflicts, ethical issues, fake peer-reviews, and data-related issues, besides providing year-wise trends regarding retraction, authorship, impact factor, and citations. We retrieved retracted publications with Indian affiliations indexed in MEDLINE between 1 January 1990 to 31 December 2021. During this period a total of 619 papers from 372 different journals with median values (interquartile range) pertaining to impact factor [3.2 (1.5, 5.2)], retraction time [24 (10, 51)] months, pre-retraction citations [4 (1, 12)], and post-retraction citations [4 (2, 12)] were retracted. While retractions still account for a small fraction of all publications (0.1%), the overall rate of retractions, that is, the number of retractions relative to the number of newly published journal articles in a given year, has been increasing. The reasons for retractions included plagiarism (27%), falsification and fabrication (26%), duplicate publication (21%), erroneous data (12%), authorship issues (4%), fake-peer reviews (3%), and ethical and funding issues (2%). We have analysed these reasons separately and compared them with each other. Besides a spurt in retraction due to plagiarism, instances of falsification have been escalating over the past decade. Half of the papers retracted on grounds of falsification were published by repeat offender authors in high-impact journals. Furthermore, 82% of retracted papers continued to accumulate citations even after the release of the journal retraction notices. The increase in retractions raises concerns over research quality as well as the wastage of scientific resources, which is especially pressing considering the present environment of scarce funding. The problem of retractions due to reasons such as plagiarism, duplicate publication, authorship issues, and, ethical issues as well as post-retraction citations can be mitigated by educating and raising awareness on publication ethics and responsible research conduct of researchers and journal publishers. Retractions due to fabrication, falsification, and fake peer reviews are more challenging to difficult to address and require further research for the identification of effective solutions.

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Introduction

Retractions in the field of biomedical research have become a growing concern, eroding the trust placed in the scientific integrity of past and future research. The frequency of these retractions can indicate shifts in scientific conduct, and efficient removal of flawed publications from the literature can help maintain the scientific integrity of the research in this field (Fanelli, 2013; Ana et al., 2013; Fang et al., 2012). Retractions in the form of journal retraction notices can be considered an indication of critical reading by the scientific community and should deter future researchers from engaging in research misconduct or publishing flawed data. These notices can also offer valuable insights for conducting reason analyses.

There are ambiguities concerning the classification of retraction reasons. Previous studies have reported differently on the increase in retraction due to errors or misconduct (Fanelli, 2013; Fang et al., 2012; Steen, 2011a). Some studies have characterised plagiarism as an inadvertent mistake (Fang et al., 2012; Steen, 2011a), while others have categorised it as intentional fraud or misconduct (Nath et al., 2006; Smith, 2006; Gupta, 2013). Further clarity is required on the classification of plagiarism as either misconduct or error, along with solutions for addressing plagiarism cases (US Office of Research Integrity (ORI), 2022; Hariman and Patel, 2014). A study conducted in India (Abinandanan, 2011) highlighted 69 retracted papers from the period 2001 to 2010, with subsequent research projects furnishing similar findings (Damineni et al., 2015; Sabir et al., 2015; Elango et al., 2019; Elango, 2021). These studies focused on limited aspects of retraction reasons and involved a small time frame. Thus, conclusions cannot be drawn on specific retraction reasons and the citations of retracted studies in the field of Indian biomedical research. The retractions in biomedical research in India exerted a notable impact on public health (Kalita et al., 2015) and have led to substantial expenditure of funds (Dandona et al., 2017). Flawed biomedical research is often associated with the duped health of the patients (Steen, 2011b; Nath et al., 2006; Rapani et al., 2020).

The editorial policies and practices of journals that influence the issuance of “retraction notices” are crucial for determining the rationale behind retractions, and reforms are required to enhance the transparency of these influencing factors (Vuong, 2020a). Continued citations of these retracted papers, even following the release of retraction notices, have introduced additional concerns (Atlas, 2004; Fang et al., 2012). Citations of retracted papers may affect the findings of subsequent research. The practice of citing retracted papers post-retraction has been ongoing since 1990 (Pfeifer and Snodgrass, 1990). It remains unclear whether the presence of these citations is merely due to subsequent researchers’ unawareness or ignorance, or if they indicate a deliberate act by journals of not representing retraction notices properly along with the publication (Bolboacă et al., 2019; Resnik et al., 2009).

No national research council in India has issued any retraction guidelines to date. Therefore, our study had two primary research objectives, first, to identify the main reasons behind the retraction of publications in the field of clinical biomedical and basic biomedical research in Indian affiliations. Second, to identify the year-wise trends pertaining to each retraction reason, the time taken for retraction, the impact factor of retracted research (IF), and the post-retraction citations of retracted biomedical research. We collected data on retraction reasons from journal retraction notices, considering all categories, including plagiarism, falsification, fabrication, duplicate publication, error in data, authorship concerns, ethical issues, funding problems, data issues, and fake peer reviews. We also collected information on citation(s) of retracted publications. The data obtained were analysed to

identify trends in retraction by year, citations, number of authors, journal IF, and time taken for retraction.

Methods

Retracted papers from India from the field of biomedical research were obtained from the PubMed database, using search options “retracted publication”, “retraction of publication”, and “duplicate publication” with the search term “India”. The search exclusively targeted studies in the English language. Every retracted paper from 1 January 1990 (the first retracted paper reported from India (Abinandanan, 2011)) to 31 December 2021 was evaluated. PubMed was searched on 5 August 2022. Following the PRISMA guidelines we identified 619 retracted papers from the biomedical research field (Fig. 1; Moher D et al., 2009). Complete articles and PDFs of retraction notices were downloaded from journal websites and dichotomised. The retraction notices for 16 papers were inaccessible on journal websites. Therefore, we searched for the print versions at AIIMS and IHBAS library facilities (primarily old subscribed print-only journals that had published retraction notices prior to 2010). The PRISMA 2020 checklist is available in Supplementary file.

Relevant MEDLINE data encompassing paper titles, publication dates, retraction dates, types (noticed/retracted/withdrawn/statement/requested/erratum/removed), retraction initiators (author(s)/editor/journal), journals’ names, authors’ names, and authors’ counts were succinctly added to an Excel sheet. Only retracted papers that were published by Indian affiliations were considered. The retracted papers with international collaborations were selected on the basis of either first authorship or corresponding authorship of Indian origin. The sentences mentioned in the retraction notices were reviewed word-by-word thrice to classify the reason for retraction. For papers retracted for more than one reason, the primary reason was identified by determining the most predominantly repeated word in the retraction notice. For duplicate publications, the duplications within the publications were verified by cross-referencing the paper title, authors’ names, and cited references. Furthermore, journal notices were consulted to ascertain the reason for retraction. Two independent reviewers conducted the selection process for determining the retracted studies to be included in the current research. Discrepancies, if any, were reviewed by the senior authors.

The IFs of the journals were assessed utilising Journal Citation Reports (JCR, Clarivate Analytics 2021). Scopus Cite Score 2021 was used in cases where IFs of journals were unavailable in JCR 2021. UGC-CARE list 2021 was also referred for information on Indian journals. Papers with missing IF were excluded from the statistical analysis. Web of Science was employed for checking citations of retracted papers. Pre-retraction citations refer to citations of a retracted publication that appear in papers of other authors prior to the issuance of the retraction notice. Post-retraction citations constitute the continued citations of a retracted publication in papers of other authors even after the release of the journal retraction notice. Citation pertaining to “retraction notice” itself was considered under pre-retraction citations, for our data analysis. The time taken for retraction was calculated in months. Journals issued alerts for retracted papers in various forms, such as by citing the main article, appending the retraction notice to the main articles’ PDF, applying a cross mark on both the retraction notice and the main paper, and using a watermark with the terms “retracted/retraction/withdrawn” on the retracted paper. These journal-initiated alerts that aimed to inform readers about paper retractions were identified and noted in our study.

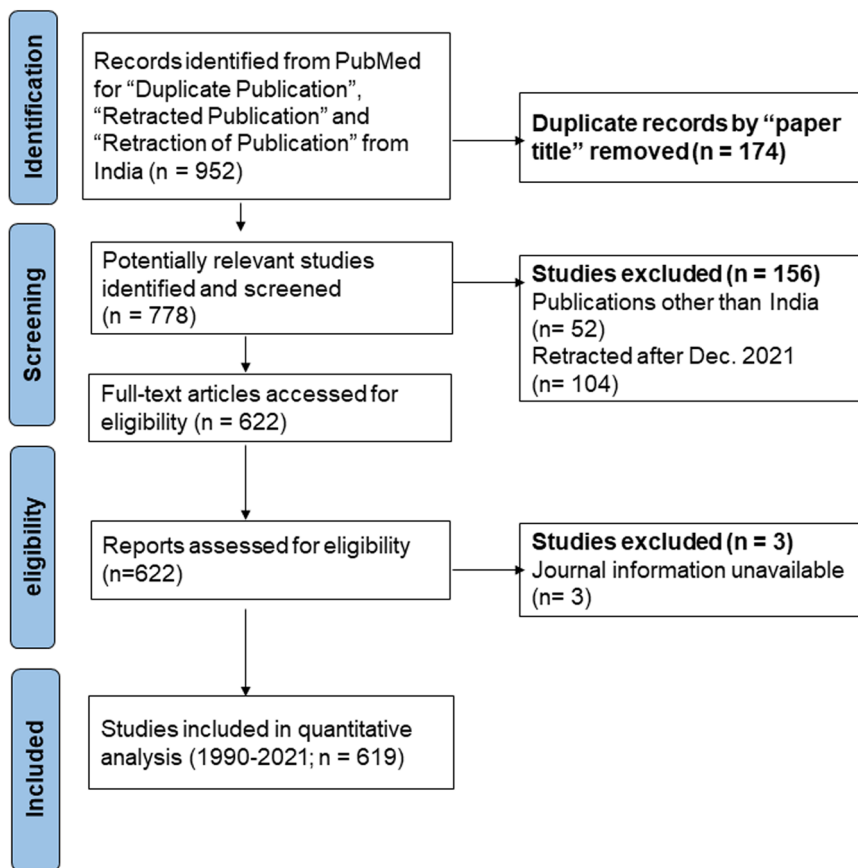


Fig. 1 Stepwise flowchart for study selection. The flowchart showing the study identification and selection of retracted articles from an initial number of records in PubMed to final sample retrieval according to PRISMA guidelines. Data accessed Aug 2022.

Statistical analysis was performed using GraphPad Prism version 8 software (San Diego, CA). Descriptive statistics was employed to compare retraction time (in months), IF and citations. The Kolmogorov–Smirnov test was used to test for normality of variable distributions. Variables that did not reject the hypothesis of normal distribution were expressed as mean \pm standard deviation (SD), whereas those that rejected the hypothesis were presented as median and described using the measure of the interquartile range (IQR). Correlations were estimated using the Pearson correlation coefficient and Spearman’s rank correlation coefficient. The non-parametric Mann–Whitney test was employed to test for differences between the two study groups (clinical and basic biomedical retractions) and citations. Publications retracted for unknown reasons were excluded from the statistical analysis. Categorical variables were expressed as frequencies with percentages and were compared using the Chi-square test or Fisher exact test, as appropriate. For all tests, statistical significance was considered as p -value < 0.05 .

Results

Number of retractions. A total of 619 biomedical research publications were retracted from PubMed from the years 1990–2021. These retracted papers had overall median values (IQR), pertaining to IF [3.2 (1.5, 5.2)], retraction time [months; 24 (10, 51)], pre-retraction citations [4 (1, 12)], and post-retraction citations [4 (2, 12)]. Year-wise trends of publication retraction in Indian biomedical research have been illustrated in Fig. 2 and provided in Supplementary Table S1. The retracted papers account for 0.1% of the total published papers in India during the selected period. Papers with Indian affiliations numbered 130,813 and 516,513

during the periods 1990–2010 and 2011–2021, respectively. The number of retracted biomedical research publications was 76 and 543 during the periods 1990–2010 and 2011–2021, respectively (Fig. 2). An increase in publication by four times and an increase in retraction by seven times were observed for the years 2011–2021 in comparison with the years 1990–2010. The first retraction of a paper from India occurred in 1992 from the *Japanese Journal of Medical Science & Biology* (published 1990) for duplicate publication by authors as they published identical data in the *Journal of Medical Microbiology*. The second retraction took place in 1993 from the *Indian Journal of Gastroenterology* due to duplicate publication. At the end of the 20th century, three papers from the field of biomedical research were retracted.

The 619 retracted papers (including 30 papers featuring international collaborations where either the first or the corresponding author belonged to India) were published in 372 unique journals. Among these, 290 journals retracted one paper, while 82 journals retracted two or more papers. *PloS One* recorded the highest ($n = 27$) number of retractions within a 54-month time frame (median value), followed by the *Journal of Biological Chemistry* ($n = 26$) in 56.5 months and the *Journal of Hazardous Materials* ($n = 11$) in 11 months. An increase in retractions of papers by repeat offenders was observed in 2008 from the *Journal of Hazardous Material*, which has an IF of 10.59 (Fig. 2, Table 1). *Life Science* and *FEMS Immunology and Medical Microbiology* each retracted four papers, which took a long time of approximately 105 months. The average time taken for retraction was 24 months for all retracted papers. We would like to highlight that we could not obtain the International Standard Serial Number for two journals and found featured on the ceased list by the University Grants Commission (UGC) of India.

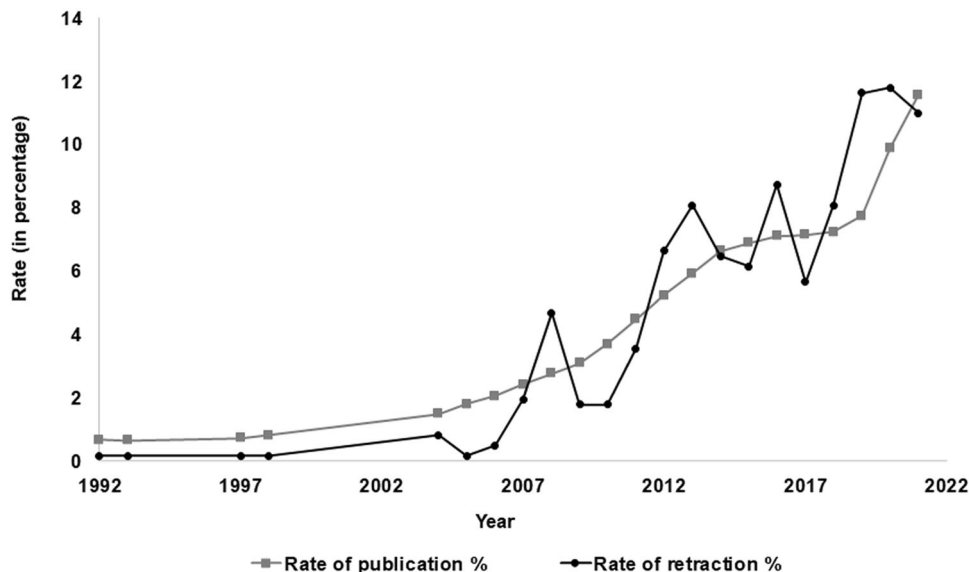


Fig. 2 Comparison of year-wise rate of publication and rate of retractions in India.

Table 1 List of journals with most retracted articles from India (>3).

Journal	No. of retracted papers	Retraction time (months)	IF (as per InCite JCR 2021)	Number of Citations until retraction notice	Number of post-retraction citations
<i>PLoS ONE</i>	27	54	3.24	7	4
<i>The Journal of Biological Chemistry</i>	26	56.5	5.49	14	4
<i>Journal of Hazardous Materials</i>	11	11	10.59	3	7
<i>Biosensors & Bioelectronics</i>	9	25	10.62	12	4
<i>Saudi Journal of Anaesthesia</i>	8	61	0.82	-	-
<i>The Scientific World Journal</i>	6	6	1.22	-	-
<i>Contemporary Clinical Dentistry</i>	6	21	1.50	-	-
<i>Frontiers in Microbiology</i>	6	20.0	5.64	2	1
<i>RSC Advances</i>	6	52.5	4.04	13	4
<i>Physiology and Molecular Biology of Plants</i>	5	33	2.39	1	-
<i>Indian Journal of Dermatology</i>	5	7	1.50	-	-
<i>European Journal of Medicinal Chemistry</i>	5	18	6.51	2	6
<i>Journal of Indian Society of Periodontology</i>	5	3	1.25	-	-
<i>BMJ Case Reports</i>	5	5	0.48	-	-
<i>Acta Biomaterialia</i>	5	20	8.95	11	16
<i>Journal of Controlled Release</i>	4	49.5	9.78	39	2
<i>Indian Journal of Dental Research</i>	4	19	2.34	-	-
<i>Life Sciences</i>	4	106	5.04	38	8
<i>ACS Applied Materials and Interfaces</i>	4	25	9.23	13	14
<i>Biotechnology Advances</i>	4	22.5	14.23	10	41
<i>Indian Journal of Critical Care Medicine</i>	4	22	0.76	-	-
<i>FEMS Immunology and Medical Microbiology</i>	4	105.5	3.08	4	1
<i>Breast Cancer</i>	4	10.5	2.04	-	-
5 Journals ^a	3	-	-	-	-

^a5 journals had three retracted articles each—*Dental Research Journal, Journal of Human Reproductive Sciences, Bioorganic and Medicinal Chemistry Letters, Experimental Eye Research and International Journal of Nanomedicine*. The above values are represented in the median.

Classification of reasons for retraction. After a thorough reading of journal retraction notices, the following terms were noted: fabrication and falsification (of image and table data); plagiarism (encompassing text, images, tables, dissertations, books, multiple

papers, study design, copyright concerns, improper citations, data overlap, content and scope); duplicate publication (pertaining to text, images, data, complete articles, scope, and content); authorship issues (involving conflict among authors, gifting of

authorship, disputes, discrepancies, uncredited contributions, and absence of acknowledgement); ethical issues (pertaining to absence of patient consent for use of image, institutional ethics, unethical practices, and infringement of code of conduct); fake peer reviews (involving falsified emails, and compromised identity); data issues (encompassing unavailability of raw or original data, doubts concerning data integrity and authenticity, misinterpretation of results, inadequate information, irreproducibility of results, and invalid article findings); technical errors (such as premature publishing, accidental repetition, and unintentional actions); and unknown. The retraction notices issued for unknown reasons were also made available by the journals, in which the reasons were explained in ambiguous terms. The terms plagiarism, duplicate publication, and fabrication and falsification are most predominantly used in the retraction notices. These terms were used as the basis for the classification of retraction reasons. The following are the operational definitions of the terminology used:

Plagiarism. The author copied text, images, data, or ideas from other author(s) in the field and published the same without citation(s) as their own original work.

Duplicate publication. The author published their own texts, images, or data repetitively without providing proper citation(s) to their previous work and presented the same as new or recent content.

Falsification and fabrication. Falsification—refers to the act of an author manipulating data (image, material, and equipment used) or selectively omitting data to fit their results to justify their hypothesis. Fabrication—occurs when an author generates false data by either creating it or cooking raw data, which is then recorded, and reported in the results and subsequent publications. Due to challenges in clearly differentiating between these two acts in the retraction notices. We considered these two actions as a combined reason for retraction to avoid bias.

Error. This category encompasses genuine mistakes or technical errors encountered by the journal or publisher during the republishing process, genuine mistakes made by authors, unavailability of old or original raw data, irreproducibility of results, and errors in data, later acknowledged by authors in notices with apologies. This category includes voluntary withdrawals initiated by authors in coordination with the journals.

Misconduct (or other reasons). This terminology was used distinctly to address papers retracted due to authorship issues, ethical issues, funding issues, or fake peer reviews.

Clinical biomedical research. Studies in this domain primarily focus on human patient material or sampling (in the form of case reports and patient data).

Basic biomedical research. Studies in this domain do not directly involve human patient material or sampling and are mainly focused on biological processes and disease pathways.

Unknown reason. The exact reason for retraction could not be determined for ~5% ($n = 34$) of the retracted papers (including eight papers from the *Journal of Biological Chemistry* alone). Although the journals had released retraction notices, the reasons remained undisclosed. Additionally, announcements were unavailable for seven papers leading to the classification of the retraction reason of these papers under “unknown”. These articles

shared some characteristics, including an IF of 2.4, a retraction time of 18.5 months, 2.5 pre-retraction citations, and 5 post-retraction citations.

Explanation of the categories retraction reasons. Plagiarism, duplicate publication, falsification and fabrication, authorship issues, ethical issues, and fake peer reviews are forms of intentional misconduct according to the US Office of Research Integrity and Medical Research Council (MRC) (US Office of Research Integrity (ORI), 2022; MRC, 1997). Our study classified each of these reasons separately. Some publications were also retracted due to unintended errors in data or technical issues. The year-wise data obtained for each retraction for 619 retracted papers have been presented in Fig. 3a. Plagiarism emerged as the predominant reason for retraction accounting for the retraction of 187 (27%) papers. More frequent plagiarism of text by authors was evidenced in 68% of these papers. The remaining papers exhibited plagiarism in data, similarity in scope and content, copyright concerns, and unattributed quotations. Duplicate publication and falsification and fabrication were noted in 143 (21%) papers and 177 (26%) retractions, respectively (Fig. 3a). A total of 47 retracted papers were published by authors in different journals using the same intellectual materials and text without citation to previous research. A few of these papers were published in another journal while still being under peer review by the first journal, resulting in subsequent publication. Five papers were retracted due to plagiarism, as the journals identified titles, content, and data similar to those published by different authors with separate university affiliations. This constitutes an infringement of professional ethics and the Code of Conduct stipulated by the Committee on Publication Ethics (COPE), which states that “submission of a paper implies that it reports unpublished work and that it is not under consideration for publication elsewhere”, in forming the guidelines of good publication ethics (COPE, 2000).

Data-related issues were cited as an associated reason for the retraction of 186 papers in retraction notices along with other reasons. A total of 58 papers were retracted for two predominant reasons (31 papers for duplicate publication and falsification, 6 papers for duplicate publication and plagiarism, 14 papers for falsification and plagiarism, 2 papers for duplicate publication and misconduct, 4 papers for falsification and misconduct and 1 paper for plagiarism and misconduct). Two papers were retracted for plagiarism, duplicate publication, and falsification. To avoid bias, we considered these reasons separately under distinct categories for statistical analysis. The misconduct category encompassed authorship issues (uncredited, ghost, or gift authorship); compromised peer-review process due to the use of fake emails; ethical issues on grounds of failure to obtain patients’ consent (breach of privacy); and funding issues. A total of 59 papers under the misconduct category were retracted for 70 reasons (Fig. 3b; including papers retracted for more than one reason). For three retracted papers misconduct was discovered later upon investigation by the journal; however, details regarding the nature of the misconduct were not mentioned. These three papers were included in the category of “unknown misconduct”. Falsification and fabrication accounted for 26% of the retracted papers. Furthermore, image manipulation was responsible for the retraction of 78% of the papers, while the remaining papers were retracted due to manipulation in table data for experiments and results. A total of 82 papers were retracted due to errors (or mistakes) in data, with the retraction taking 11 months. Overall, these papers were retracted for 682 distinct reasons (21 papers with 3 reasons, 77 papers for two reasons, and the remainder for one reason) (see Supplementary Table S2).

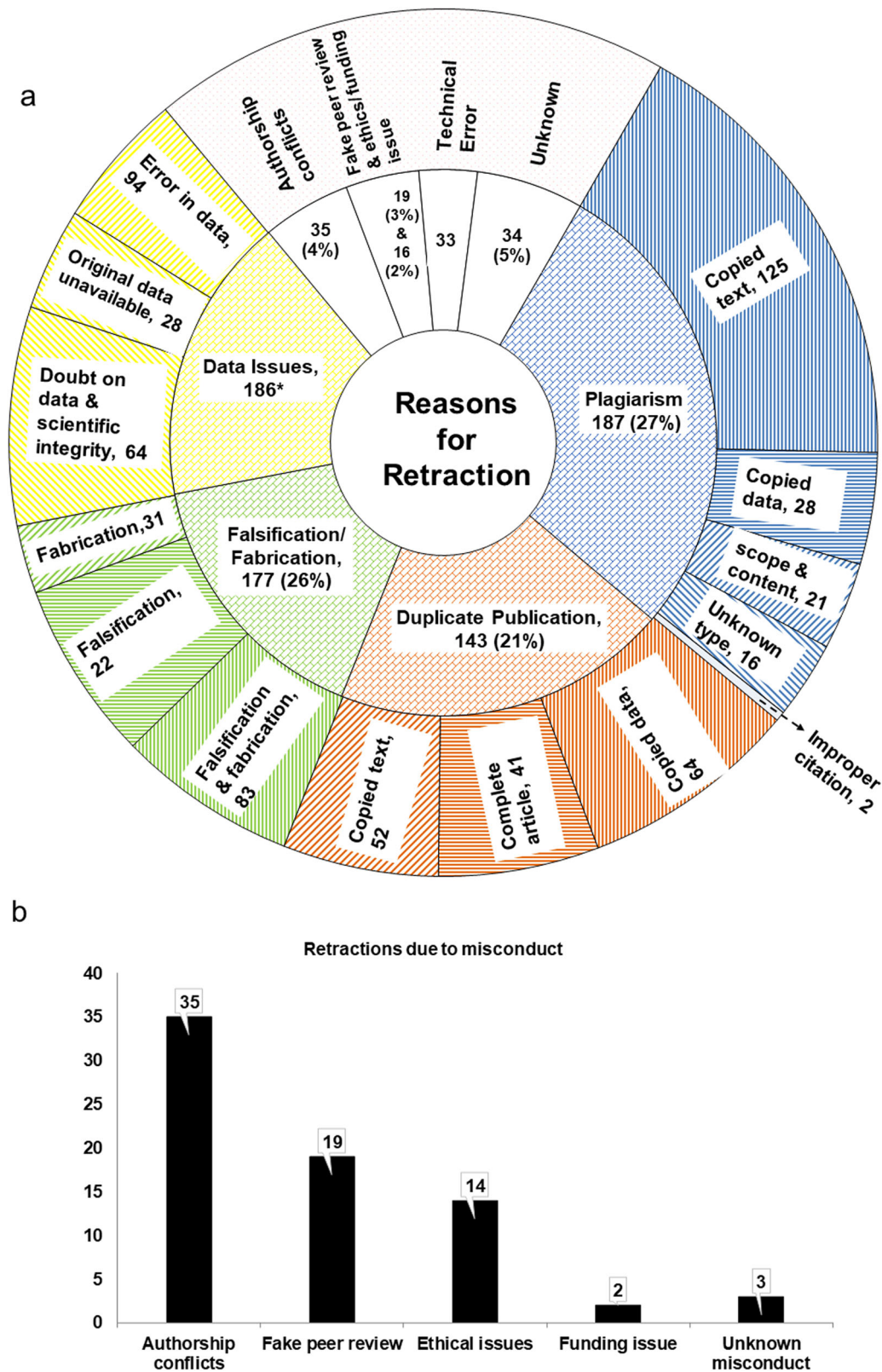


Fig. 3 Classification of biomedical research retracted articles ($n = 619$) from India. Classification based on the reason for retraction (a and b).

Study type: Clinical biomedical research and basic biomedical research. The retracted papers' abstracts and complete texts were evaluated to classify the papers into two study types: clinical biomedical research papers ($n = 172$; involved human materials, including 57 case reports) and basic biomedical research papers

($n = 447$; did not utilise human sampling or materials). The retracted basic biomedical papers had a higher average IF of 3.8 compared with the clinical biomedical papers, which had an average IF of 1.4. Although plagiarism was the most common reason for retractions in both clinical and basic biomedical

research categories, falsification was responsible for the retraction of a large number of papers within the basic biomedical research category. Retraction reasons such as authorship issues and ethical issues were predominantly observed in clinical biomedical research retractions ($n = 23$). The retracted clinical biomedical papers raise concerns regarding the quality and reliability of these articles, more so because of their focus on human health. Total citations were higher for basic biomedical papers than for clinical biomedical papers. Interestingly, post-citations and pre-citations were 436 and 382, respectively, for clinical biomedical publications. The overall number of citations for all retracted publications has been presented in Supplementary Fig. S1.

Time taken for retraction, year-wise trends in retraction reasons, and journal impact factor. The time taken for retraction was 27 months for basic biomedical papers and 15.5 months for clinical publications. Journals took less time to identify and retract publications that primarily had authorship issues, ethical issues, and fake peer reviews. Journals took longer time to identify and retract publications on grounds of due to fabrication and falsification than they did for cases with text overlaps in duplicate publications and plagiarism (Supplementary Table S2). *One paper which was retracted due to plagiarism, stood out due to its longest retraction time of 266 months.* Retractions due to plagiarism were prevalent in India by the year 2004 and those due to fabrication or falsification by the year 2008 (Fig. 4a). Plagiarism saw an increase after 2010 (reaching a peak of 21 plagiarised papers in 2012). Misconduct was most prevalent in the year 2016, with a majority of analysed papers published in the *Scientific World Journal* facing retraction for reason fake-peer review processes undertaken by authors using fake email accounts. Retraction notices for repeat offender authors (same set of authors and affiliations) were published in the *Breast Cancer Journal*. In India, retractions for duplicate publications have been recorded from before 2000 (retraction time = 105.7 months). This trend has shown a decline with the minimum average retraction time reaching 2.8 months in 2018 ($R^2 = 0.69$, $p < 0.001$). Notably, 32% of the publications ($n = 200$) were retracted within 12 months of publication, with thirteen papers being retracted on the same day of publication due to technical errors and author conflicts. One paper was retracted from the *New England Journal of Medicine* due to image fabrication within 18 days of publication.

Overall, each retracted paper had a median IF of 3, out of which 69% had an IF < 5 and 41 retracted papers had an IF > 10 . The journals with very high IF (> 10) completed retraction in 25 months, while journals with low IF (< 5) accomplished the same in 21 months. The papers retracted for falsification and fabrication had a median IF of 4.6. The IF of these papers ranged from 0.2 to 12.54, with the exception of two that had the highest IF of 91.25 and were retracted in 2013 and 2019 from the *New England Journal of Medicine*. An outlier in this case, the 2013 paper was retracted due to falsification and fabrication of data and images, in 22 months, with 79 pre-citations and 116 post-citations. The paper retracted in the year 2019 had been published just 18 days prior to publication (Fig. 4b and d). Falsification was the most cited reason accounting for the retraction of 49 papers by five journals, namely *Acta Biomaterialia*, *Biosensors and Bioelectronics*, *Life Sciences*, *Journal of Hazardous Materials* and *PLoS ONE* (Table 1). Journals that retracted papers for plagiarism, duplicate publication, and misconduct had IFs ranging from 2 to 2.5. The IFs for 21 retracted papers were unavailable. Therefore, these were excluded from the statistical analysis.

Pre-retraction and post-retraction citations. Overall, the retracted papers had 5809 citations before the issuance of the

retraction notice and garnered 4027 citations after the notice's release in 372 unique journals. Furthermore, 25% of the retracted papers had a greater number of post-retraction citations compared with their pre-retraction citations. Papers retracted on grounds of fabrication and falsification had a total of 4752 citations (average of 27 citations per paper), whereas those retracted due to plagiarism had a total of 3286 citations (average of 18 citations per paper). Basic biomedical research papers accumulated a significant number of citations primarily due to their publication in the form of review papers (1172 citations post-issuance of retraction notices with a median of 14 citations for each retracted review paper).

Number of authors. The 619 retracted papers were published by 2753 authors, including 199 authors among which 199 authors were "repeat offenders" with at least two retracted publications and another 119 were repeat offenders with 3–14 retracted publications. The mean \pm SD for the number of authors per retracted paper was 4.4 ± 2.5 , and the mode was 136 for three authors. The graph in Fig. 4e for the number of retracted papers and the number of authors can be seen in two phases: The first phase reveals a rapid expansion starting with 5.3% ($n = 33$) of retracted publications authored by single author, followed by, 15.5% ($n = 96$) authored by two authors, and 22% ($n = 136$) involving three authors, and the median retraction time of these papers was 17, 25.5, and 20 months, respectively (Fig. 4e). The second phase demonstrates a decline with 117 articles authored by four authors, and 68 by five authors, decreasing to as low as two papers by 13 authors, and one paper each by 15, 16, and 23 authors. The second phase reveals an inverse relationship with the increase in the number of co-authors, a decrease in the number of retractions was observed. However, the presence of multiple co-authors does not guarantee immunity from retractions, as certain cases with ≥ 10 co-authors were still retracted due to falsification and plagiarism (Steen, 2011c). Retractions involving a single author indicate a lower likelihood of employment of unfair practices compared with cases involving two, or three authors, in which the burden and risk are seemingly shared.

Whistle-blowers. In the case of 33 papers, readers acted as whistle-blowers, identifying incidences of misconduct and alerting the journal editor. Journal editors then investigated these papers, resulting in erratum, correction, and retraction. A majority of retractions were issued due to requests by editors-in-chief and/or the journals (498); followed by agreements between editors and authors (68); authors initiated appeals (36); and collaboration between editors-in-chief, journal publishers and institutional investigation committees (24). When authors requested retractions, it was primarily due to errors in data and other data-related issues, as described in previous research (Vuong, 2020b). Papers retracted primarily due to falsification reasons involved institutional panels or committees, in addition to editors-in-chief, other editors, and journals to in the retraction decision. Final decisions were taken by the editors-in-chief of journals.

Phrases used for retraction and issuance of alerts by journals. The different types of retraction notices employed various phrases, which are listed in Table 2. "Retracted (requested)" should not be confused with the retractions requested by authors. The latter was evaluated by assessing the words or sentences mentioned in the retraction notices. Journals bore the responsibility of alerting their readers about retraction through various ways including labelling on their websites, appending the PDF of the retraction notice to the main article, utilising watermarks, and placing a cross mark

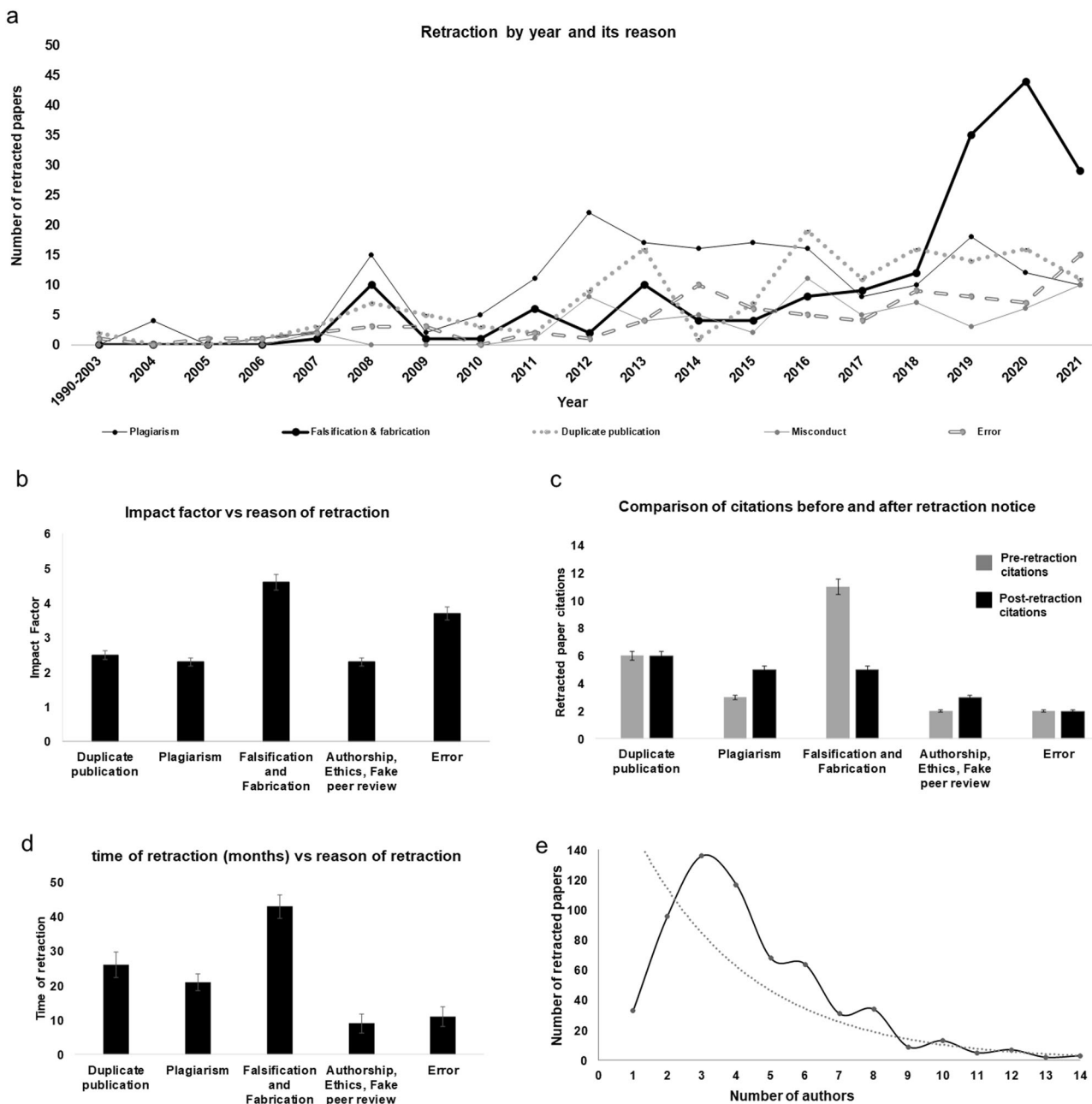


Fig. 4 Trends in retraction as per their reason. The number of retracted papers and their reasons per year (a), the median impact factor of journals (b), comparison of the pre-retraction citations and post-retraction citations (c), the median time taken (in months) for retraction (d), and the number of author distribution for each retracted paper (e).

on the paper. The alerts employed by the journals to inform readers about the paper retraction are listed in Table 3. Although 603 retracted papers were accompanied by PDFs of retraction notices on journal websites (except 16 retracted papers that had only print versions of retraction notices available and were retracted before the year 2010), only 304 papers were watermarked. These watermarks, which were red or grey conveyed the phrase “retracted”, “retraction of publication” or “withdrawn”. The *Chinese Journal of Lung Cancer* used the colour blue in its retraction watermarks. Cross marks in red were found in only 113 retracted articles. Furthermore, 25.4% of the downloaded complete papers were accompanied by PDFs of retraction notices. It was surprising to note that only 139 articles contained both watermarks and cross marks, while only 31 articles had all three. The journals did not employ prominent markers for alerting

readers for 31% of the papers, which might have led to them receiving post-retraction citations.

Discussion

In this study we report evidence confirming that research papers with Indian affiliation are retracted more due to misconduct including plagiarism, duplicate publication, falsification, authorship issues, ethical issues, and fake peer reviews than errors (Fig. 3). Although we found a progressive increase in biomedical research publications from India, it does not take away from the fact that retractions are increasing at a higher rate than before, as observed in recent years (Fig. 2; Supplementary Fig. S2). This is not a healthy trend. Retractions due to duplicate publication were first reported in India in the year 1990, and such cases have been persisting at a steady rate since then. Plagiarism first appeared in

Table 2 Phrases used in the retraction notices.

Phrase used for retraction	Number
Retracted	232
Retracted (retraction notice)	184
Retraction (retraction notice/retraction note to/retraction of)	98
Retracted (withdrawal/withdrawn)	43
Retracted (statement of retraction)	13
Retracted (retraction note/note to)	5
Retracted (editorial retraction)	1
Retracted (removed)	1
Retracted (requested)	1

Erratum has been published for 19 papers for correction, which later led to retractions based on paper-related concerns of error, plagiarism, falsification and other misconducts. Also, papers share more than one phrase for retraction of the paper.

Table 3 Alert to readers by the journal.

Where noted retraction	Retracted papers, n (%)
Retraction note PDF available by Journal website	603 (97.4)
Retraction note cited and/or PDF appended to the published article	157 (25.4)
Watermark on published article PDF	304 (49.1)
Cross Mark on published article PDF	113 (18.2)
Retraction note not constituted anywhere with the published article	192 (31.0)

2004 (the highest number of retracted papers [22] observed in 2012), followed by falsification in 2008 (the highest number of retracted papers [44] observed in 2020). It is evident from the data that 48% of the papers were retracted due to plagiarism and duplicate publication. This can be attributed to the “publish and perish culture” (De Rond and Miller, 2005). Furthermore, the readily available electronic access to publications and technological advancements in word processing have greatly promoted plagiarism over the past years. Retraction due to plagiarism has been decreasing in recent years due to the implementation of facilitation of plagiarism detection software and tools and strict guidelines (Horrom, 2012; UGC, 2021; Fig. 4a). However, we still lack software and guidelines for addressing the dealing falsification of images and data. This could possibly be the primary reason behind the trend of increasing retractions due to falsification and fabrication. The number of research publications is indicative of a scholar’s talent and their standing among peers. It leads to invitations to talks, committee membership at institutions, and opportunities to serve as reviewers or editors for journals, bestowing recognition, and credibility on the scholar (Sabir et al., 2015). Publication makes scholars more appealing to funding agencies, which improves their chances of obtaining grants and enhances their candidacy for recruitment or promotion (De Rond and Miller, 2005). In India, many scientists face disparities in research funding, which forces them to resort to publishing subpar work (Kalita et al., 2015; Dandona et al., 2017). These authors prioritise having their names on articles over upholding basic publication ethics, often resorting to plagiarism or duplication. Most of the time, faculty members and research scholars are bound by their institutional degrees/course work/project guidelines to publish, which puts them under pressure to perform this duty (Smith, 2006; Elango et al., 2019). Publications by new and untrained researchers often face retractions due to proofreading oversight by senior colleagues or faculty members. Furthermore, the absence of proper guidelines to follow exacerbates these issues.

COPE classifies plagiarism and duplicate publications as distinct categories of retraction reasons (COPE, 2000 guidelines). The classification of plagiarism involving data but not text under the category of misconduct is contradictory (Steen, 2011a; Fang, 2012). Fang (2012) considered plagiarism separately in a subsequent paper, highlighting that India and China collectively accounted for a greater number of retractions due to plagiarism and duplicate publication than the United States (Fang et al., 2012). The MRC code classifies plagiarism, falsification, and fabrication as forms of misconduct, but it does not include honest errors (MRC, 1997). We believe that plagiarism of text, ideas, data, and images all of which are grounds for paper retraction should be taken seriously. Therefore, to bring the retraction reasons of plagiarism and duplicate publication to the attention of scholars and journals, we classified them separately. Authors have republished their data and images to earn credit without due reference and have largely duplicated texts within their Introduction, Method, Discussion, and Conclusion sections. In case there is a chance of the same article being published by two journals, it is the duty of the author to request the withdrawal of the article from the first journal prior to submitting it to another journal.

However, with time plagiarism and duplicate publications are becoming easy to detect through plagiarism detection software. These programs have been made available (free or on a payment basis) at large to all Indian institutions and their faculties aiding the detection of text overlap in research articles. Furthermore, the Indian Government’ (UGC), has issued a strict guideline mandating the use of “plagiarism-detection programs” for submitted manuscripts and theses, which is largely followed by numerous journals. However, these programs cannot detect “idea plagiarism” in manuscripts. The UGC has also introduced a two-credit course on publication ethics and publication misconduct, which is mandatory for all PhD students (UGC, 2019). Academic Integrity Panels have been established to investigate complaints concerning plagiarism and impose appropriate penalties on guilty researchers according to the graded level of plagiarism, ranging from minor actions to termination of service (UGC, 2021). This could be the reason behind the decrease in the number of retractions due to plagiarism and duplicate publication, as evident from our analysis (Fig. 4a).

India has strict defamation laws, and Article 19(1)(a) of the Constitution of India safeguards the right to free speech. However, this right does not extend to defaming individuals and harming their reputations through libel or slander (Constitution of India). These laws could apply to the research field as well. But, to the best of our knowledge, no Indian authority has published any guidelines regarding research integrity and publication, to best of our knowledge. It is challenging to determine whether defamation laws have any influence on the 5% of cases from India that have been retracted for reasons that have not been disclosed by journals in their retraction notices (Fig. 3a, Supplementary Table S2). Our data lacks details regarding this aspect.

In addition to being the authors’ responsibility, it is also the duty of journals to review manuscripts carefully for plagiarism before sending them to external reviewers. In one of the retractions notices the editor-in-chief of the journal *Pharmacy Practice* discussed the concepts of plagiarism and misconduct, stating that “plagiarism is a concept without a clear definition...all types of scientific misconduct constitute a frequent and serious problem that we all should be aware of and address together” (Fernandez-Llimos, 2012). In cases of duplicate publication, journals may ask authors to submit the previously published papers along with their manuscripts.

Fabrication and falsification have been increasing rapidly and continuously at twice the rate of plagiarism (Figs. 3a and 4a).

These papers are primarily published in high IF journals and boast a high number of citations (Fig. 4b and c). Fraud takes a longer time to identify compared with other retraction reasons (Fig. 4d). Deliberate fraud (fabrication or falsification of data) by multiple collaborating authors has been observed. These fraudulent authors typically target high IF journals and have other fraudulent publications with shared authorship (Steen, 2011c). Even in our data analysis, we discovered that retracted papers involving falsification and fabrication of data and images were published by “repeat offenders” who are co-authors in multiple papers. These repeat offenders were found to be published extensively in journals with IFs ranging from 3 to 12 and mostly target high IF journals. More than 50% of such retracted papers have ≥ 4 authors who are repeat offenders. In addition, these papers were published repeatedly in primarily the same type of journals (Table 1). Identifying and investigating repeat offenders might have taken journals a significant amount of time (Fig. 4d). The repeat offenders were authors found guilty of repetitively using the same data and figures to validate the results of different scientific experiments in various publications. Restrictions were imposed on future activities at their universities. The veracity of their published research project across all journals has become doubtful, and they are regarded as potentially fraudulent. Publications in high IF journals are associated with the prestige of a scientist, which places significant pressure on them, leading them towards increased errors and falsification for publication. These issues need to be subjected to critical examination and strong observation during the review process. These papers may have come to attention late because of the limited and restricted availability of software for detecting falsification and fabrication of image data, an issue that remains unknown at many research institutions. However, due to clear policies established by a majority of high IF journals, post-retraction citations of these fraudulent journals are comparatively less (Fig. 4c). An analysis of retracted biomedical research papers revealed that 53 papers in the field of dental research were retracted primarily due to falsification. Similar trends have been observed for retractions in dental research from India, with 49 out of 180 retracted papers originating in other countries (Rapani et al., 2020). We wish to report a specific retraction notice involving a dental research paper. The author of this paper had previously served as a reviewer for the *International Journal of Paediatric Dentistry*, which was when he rejected a manuscript submitted by another researcher. The same manuscript was later published in the *Journal of Conservative Dentistry* under this authorship (Retraction, 2016). The journal’s editorial office later retracted this paper.

Fake peer review is a type of manipulated peer review, wherein an author uses fake email addresses to provide review suggestions. The author fabricates favourable reviews, facilitating the acceptance of their own paper (Misra et al., 2018; Fig. 4b). Researchers must obtain ethical permissions from Institutional Ethical Committees prior to publication for human or animal sampling and seek patients’ consent before using their images in case reports or clinical research studies to avoid retractions in future.

Authorship disputes among researchers are common; however, the contribution of an author can be assessed through careful discussions in lab research groups or among research collaborators before submission. The ranking of authors constitutes a critical aspect of scientific research and should be decided on prior to publication to avoid retractions. Arguments are common in the research field; however, they should be approached carefully to avoid misconduct accusations.

Committing honest errors in scientific research cannot be deemed as misconduct. Errata are published seeking corrections in papers when the errors are not severe enough to warrant full retraction (Nath et al., 2006). Errata for correction was published

for 16 papers; however, the papers were later retracted by journals on grounds of failure to produce results, unavailability of raw data by authors and technical issues. Papers retracted due to errors may be a result of honest mistakes by journals or publishers due to technical issues leading to the publication of the same article twice. Such retracted papers can spark constructive debates among researchers. Authors should shoulder the responsibility of promptly any error in the data to report journals. Such actions constitute a component of good research practice and foster a culture of robust scientific explorations.

The retraction announcements issued by journals were discovered to have similar patterns in disclosing the reason for retraction. However, the *Journal of Biological Chemistry* does not disclose the retraction reason in its notices. There must be a common guideline and policy concerning retractions that can be followed by all journals without bias (Wager et al., 2009). This will reduce the long time taken by journals for retraction. The retraction of the most highly cited papers can be largely attributed to plagiarism in the form of review articles. The most cited retracted articles from India and the reasons for their retraction have been listed (Supplementary Table S3). Overall, the number of post-retraction citations is found to be higher than that of pre-retraction citations for the retracted papers (Fig. 4c). Falsification led to the retraction of 75% of the papers published in high IF journals. These papers were either watermarked or cross-marked by the journals (Table 3). A significant difference can be expected once retraction notices are made readily available, enabling the removal of retracted articles to prevent their further use. Journals may take a long time to retract papers, and ignoring alerts by capitalising on ambiguities and discrepancies in retraction notices helps journals maintain their IF, which upholds their reputation and helps them reap benefits. Citations of papers tend to increase over time, and we found a positive correlation between citations and retraction time. As more time passes, more researchers will read and cite an article. Post-retraction citations can lead to another form of misconduct often overlooked by journals and cited by researchers due to unawareness or oversight, possibly indicating that the alerts are not being read or are being purposely ignored. However, studies published by authors who have cited retracted articles become questionable. The onus of pre-retraction citations rests on the authors and the publishing journal. Simultaneously, the onus of post-retraction citations rests mainly on the researcher who has included these citations. Therefore, such studies should also be scrutinised to avoid such citations. Journals play a critical role here in alerting readers about retractions (Table 3). To avoid misconduct in research publications and maintain scientific research integrity, we would like to suggest the following recommendations based on our findings:

1. *Training of researchers:* First and foremost, the training of undergraduate, postgraduate, and post-doctoral research students is necessary. The UGC has mandated a two-credit course on publication ethics and publication misconduct for all PhD students (UGC, 2019). These courses should be conducted at regular intervals for all researchers at any stage, ranging from undergraduate to faculty levels.
2. *Careful use of citations:* Scholars must maintain research integrity by citing previous literature carefully. Self-citations are also crucial for avoiding retractions due to duplications.
3. *Contribution of authors:* Authorship ranking and contributions must be determined before writing the manuscript. The international guidelines on authorship issued by COPE (2000), CSE (2021) and ICMJE (2021) must be followed.
4. For biomedical research papers, ethical clearances must be obtained before seeking grants or at least before drafting the manuscript. Patients’ consent must be sought for using patient data or images well in advance.

5. *National and international guidelines*: Indian researchers should follow national and international guidelines while publishing to ensure responsible research conduct (RCR) (DBT, 2016; ICMR RIPE, 2019; UGC, 2018; UGC, 2019) and international guidelines (COPE, 2000; CSE, 2021; ICMJE, 2021). These guidelines concerning publication ethics and responsible research conduct must be revised and updated regularly.
6. Webinars, seminars, or workshops must be regularly organised at all institutions for raising awareness and researchers who abide by these guidelines must be awarded.
7. *Appropriate addressal of retraction reasons*: Different forms of misconduct (namely plagiarism, duplicate publication, falsification, fabrication, authorship issues, ethical issues, and fake peer reviews) must be addressed with distinct solutions. The degree of misconduct should be decided and subsequent penalties should be imposed accordingly.
8. Journals and editors must adopt transparency and clarity when releasing retraction notices and cite reasons without bias. All journals must follow a universal guideline for issuing retraction notices. Further reforms to enhance the transparency of retractions have been suggested by Vuong (2020a).
9. Issues such as plagiarism, duplicate publication and falsification can be avoided by early use of plagiarism and falsification detection tools at the time of peer review itself to avoid retractions in the future.
10. The issue of duplicate publication can be avoided through a thorough investigation of all previously published studies by authors at the time of the peer review process. Journals can ask authors to provide all their published studies along with a plagiarism report at the time of manuscript submission.
11. The journals must meticulously provide alerts to the readers informing them about paper retractions of paper by attaching PDFs of retraction notices, applying watermarks, or placing cross-marks on the entire paper. This will help reduce future citations of retracted papers.
12. All citations in a manuscript should be checked carefully for retracted papers by journals before sending it for external peer review and publication as well as by authors at the time of submission. It is unethical to cite an article solely based on its previous citations. The full text of the articles must be thoroughly read by authors before citing the same (Bolboacă et al., 2019).
13. To avoid paper retractions due to genuine mistakes or errors in data, authors should be given the opportunity to make scientific corrections in their papers through published errata/ or demand for corrections. This move should be adopted instead of resorting to full retractions.
14. In India, the UGC has released guidelines to avoid predatory publishing and has provided a list of cloned and predatory journals in the UGC-CARE list, which is revised regularly (Patwardhan and Nagarkar, 2021).

The strength of this research lies in its qualitative analysis of the distinct reasons that lead to retraction and its uncovering of the ambiguities pertaining to research integrity. The primary aim of this paper was to highlight the exact reasons for retraction in Indian biomedical research as well as the inclusion and exclusion criteria for the retracted papers. Therefore, other retraction sources, subjects or countries have not been covered here. Retraction notices issued during 1990–2021 have been covered, and they provide a lower estimate of the number of papers potentially retracted during this period. The analysis of the retraction reasons is based on the information obtained from the words and sentences employed by journals in their retraction notices. The data provided by journals concerning retraction reasons may have informed the results and could have also

undermined its credibility if the reasons were not disclosed transparently. Additionally, the study findings might present an underestimation of the total number of retractions due to the study's exclusive reliance on the PubMed database (which started recording errata from 1987 onwards). However, the significant strength of this study lies in its complete coverage of biomedical research papers from India. Scopus Cite Score 2021 was utilised for cases where the IFs of papers were unavailable in JCR 2021. This paper does not delve into an empirical analysis of the impact of retractions on the number of subsequent citations. To perform such analysis, information on additional “matching papers” that were not retracted would be required. Conducting such an analysis would be useful for future research. This paper did not assess the research quality of papers and retraction-based relationships. The quality and validity of retracted papers need to be reviewed further, as these retractions do not entirely invalidate the retracted papers. However, retractions in medical research, especially those of case reports, are of utmost importance as they influence patient health and treatment decisions.

Science requires a comprehensive system to safeguard its underlying values, and retraction constitutes an important tool for upholding these values. Today's problem with eroded trust in the sciences, there is a need for a renewal of integrity, transparency, and intellectual honesty. Ignoring the issues highlighted and explored in this research article may lead to inflated costs of doing science and could pose obstacles to securing additional or future funding (Vuong, 2018). The problem of retractions due to plagiarism, duplicate publication, authorship issues, ethical issues, and the like as well as the issues of post-retraction citations can be avoided by educating and increasing the awareness of researchers and journal publishers. Retractions due to fabrication, falsification, and fake peer reviews are issues that stand as pressing concerns that require further investigations for the identification and implementation of potentially ideal solutions. The results presented concerning the various reasons for retraction in India-affiliated biomedical research, year-wise trends, impact of retractions on clinical and basic biomedical research, and post-retraction citations will help raise awareness among researchers. This paper has the potential to improve scientific research by authors by encouraging them to exercise caution and avoid misconduct as well as post-retraction citations while publishing. The findings from our study can serve as a reference for future investigations and the development of guidelines.

Data availability

The datasets supporting this article will be provided on reasonable request email to the corresponding author.

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The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

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