ORIGINAL ARTICLE

COVID-19 vaccination status and willingness for further booster doses among staff and students of a tertiary care institute

Meenal Madhukar Thakare, Nikita Sharma, Sunidhi Karol

Department of Community and Family Medicine, All India Institute of Medical Sciences Bilaspur, Himachal Pradesh

CORRESPONDING AUTHOR

Dr Nikita Sharma, Assistant Professor, Department of Community and Family Medicine, All India Institute of Medical Sciences Bilaspur, Himachal Pradesh, India, 174037

Email: nikkizoan@gmail.com

CITATION

Thakare MM, Sharma N, Karol S. COVID-19 vaccination status and willingness for further booster doses among staff and students of a tertiary care institute. Indian J Comm Health. 2025;37(4):566-572.

https://doi.org/10.47203/IJCH.2025.v37i04.011

ARTICLE CYCLE

Received: 17/02/2025; Accepted: 12/07/2025; Published: 31/08/2025

ABSTRACT

Background: Vaccination remains the mainstay of COVID-19 prevention. While initial vaccine acceptance was high among healthcare workers (HCWs), the emergence of new variants and waning immunity necessitated vaccine boosters. The study aimed to ascertain the COVID-19 vaccination status of the staff and medical students of a tertiary care institute and their willingness for further booster doses. **Methods:** An observational study was conducted among healthcare workers (doctors, nurses, technicians), ancillary staff, and students. An online semi-structured questionnaire collected information from participants regarding sociodemographic characteristics, history of COVID-19 vaccination, acceptance and uptake of booster dose, and reasons for willingness to uptake booster. The Chi-square test assessed the association between sociodemographic variables and booster acceptance. **Results:** About 302 people filled the survey questionnaire. Most of the participants belonged to the 18-29 year age group (61.3%) and worked in the clinical departments (54.3%). The majority of them had received the Covishield vaccine (71.5%). Half of them had already received a COVID-19 booster. Seven out of ten participants were willing to uptake further vaccine booster. Being a healthcare worker and working in non-clinical department was significantly associated with booster acceptance. The perception of the COVID-19 vaccine as an immunity booster was a key motivator. About 15.1% of participants expressed a preference for a nasal booster for its convenience in administration. **Conclusion:** The study highlights a high willingness for COVID-19 vaccine boosters among healthcare professionals and medical students. It emphasizes the importance of continuous efforts to promote vaccine boosters, given the crucial role of the medical community in shaping public perception.

KEYWORDS

COVID-19 Vaccine; Booster Vaccine; Vaccine Acceptance.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) has necessitated an unprecedented response, with vaccination playing a pivotal role in preventing the disease spread. India approved two vaccines (Covishield and Covaxin) against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in 2021.(1) Healthcare workers (HCWs) who faced a high risk of exposure to SARS-CoV-2 were prioritized to receive the vaccines.(2) The initial rollout of COVID-19 vaccines saw high acceptance rates among HCWs.(3)

Vaccines generate systemic immunity, protect against severe disease, and further reduce the risk of long COVID among infected individuals. The antibody response against SARS-CoV-2 declines over time. Subsequently, the clinical protection offered by the vaccines decreases. A surge in COVID-19 cases was observed in India in December 2021-January 2022, attributed to the Delta and Omicron variants, with various subvariants gaining prominence during 2022.(4) Despite effective vaccines, the rapidly mutating nature of the SARS-CoV-2 virus and the emergence of new virus strains

threaten the progress made against the pandemic. High viral loads were observed among vaccinated individuals infected with novel Omicron variants compared to those infected with older Delta and Omicron variants.(5) The continuous evolution of the virus, the appearance of variants of concern (VoC), and waning immunity led the WHO to recommend additional booster doses of mRNA vaccines against COVID-19 in 2022.(6)

Healthcare workers, the elderly, and immunocompromised individuals were at an increased risk of infection. The Indian government prioritized the booster dose for HCWs, frontline workers, the elderly, and adults with co-morbidities.(7) These individuals were eligible to receive a booster dose after completion of nine months from the administration of the second dose. A survey conducted in urban Delhi reported that nearly 42% of residents above 50 years did not uptake a COVID-19 booster despite a high proportion of participants receiving two doses of a primary series of vaccinations.(8) A repeated cross-sectional survey conducted among healthcare workers in India observed an increase in willingness to receive the COVID-19 vaccine with time.(3) The acceptance of booster doses has been more variable, ranging from 55.3% among HCWs in Saudi Arabia to 71.3% among Czech HCWs.(9,10) A study in Saudi Arabia found that while a majority of HCWs knew about the Delta variant, few HCWs had sufficient knowledge about it, and just over half were willing to take the vaccine booster.(10) Vaccine boosters have introduced new complexities concerning vaccine acceptance and coverage, especially among the HCWs.(8,10,11) Vaccine booster hesitant individuals were more likely to be unvaccinated.(9) There is insufficient information regarding the coverage of the COVID-19 vaccine booster and its acceptance among Indian HCWs.

Aim and objectives

We aimed to ascertain the COVID-19 vaccination status and willingness for further booster doses among the staff and medical students in a tertiary care institute.

The objective was to explore the reasons for participant's willingness to uptake further booster doses and their preference for the nasal route.

MATERIAL & METHODS

Study design: The study was cross-sectional and was conducted among the healthcare workers, staff and students at a medical college and hospital in Himachal Pradesh. The study setting included all departments within the college, encompassing paraclinical, clinical, and administrative staff to provide a comprehensive view of the population.

Study population: The target population comprised healthcare professionals including physicians, residents, nurses, pharmacists, technicians, ancillary staff, and medical students of the institute.

Sample size: The sample size calculation was based on the college's estimated number of staff and medical students ($N_{finite} = \frac{n_\infty}{1+\frac{n_\infty - 1}{N}}$, $where$ N=1100). Considering the intention to uptake a vaccine booster as 55.3% (10), with a margin of error of 5%, and a confidence interval of 95%, using the formula n= $\frac{Z_{1-\alpha}^2 pq}{d^2}$, the sample size was calculated as 283. Assuming that 10% of participants may not respond to the survey, which resulted in a sample size of 312 participants.

Sampling strategy: The study participants were recruited using a convenience sampling technique. They were invited through email and WhatsApp to participate in the study.

Inclusion criterion: All staff members employed at the institute and medical students enrolled in the college who were ≥ 18 years old and had a smartphone were eligible to participate.

Exclusion criterion: The participants who did not have access to a smartphone or did not give consent for the survey were excluded.

Study tool: A semi-structured questionnaire was prepared after reviewing the literature from similar studies.(9,10) It had a cover page and three sections including (1) sociodemographic characteristics (age, gender, occupation, department), (2) COVID-19 vaccination history (no. of vaccine doses and type of vaccine received, perception and attitude regarding vaccine booster, reasons for willingness for booster dose), and (3) history of COVID-19 infection. The clarity and comprehensibility of the questionnaire were assessed by two external public health experts to ensure its validity. The questionnaire was created in English and translated into *Hindi* and the participants could choose either version. The questionnaire was self-administered. An online survey platform was used to share the questionnaire with the participants via email and WhatsApp. The online platform was used to ensure anonymity and data security for all participants.

Study duration: The study was conducted over 2 months during the winter season (December 2022 – January 2023).

Ethical consideration: The study was approved by the Institute's Ethics Committee (No. 46/23). After elaborating on the study objectives, their rights as participants, and instructions for completing the survey on the cover page, electronic consent was obtained from participants in the form of "Yes" or "No" for their willingness to participate in the study. Only after replying "Yes", they could access the

main questionnaire. Data was anonymized to maintain their privacy.

Data analysis: The data was downloaded as a Microsoft Excel comma-separated value (.csv) file and analyzed using Statistical Package for Social Sciences (SPSS) version 24.. Descriptive analysis was performed and results were displayed as frequency and percentages for categorical variables and mean (S.D.) for continuous variables. Chi-square test was used to assess the association between sociodemographic variables and booster acceptance.

RESULTS

About 302 participants responded to the survey (non-response rate = 3.2%). Over half of them were females and belonged to the 18-29 year age group (61.2%). Most of them were employed as ancillary staff (30.5%), nurses (26.8%), students (22.2%) and doctors (10.9%). Over half of them were working in the clinical departments (54.3%) and the rest in pre-clinical or para-clinical departments. The majority of them had received the Covishield vaccine (71.5%) followed by Covaxin (16.2%) and Sputnik (0.3%). One-tenth of the participants who could not name the vaccine received were sanitary attendants. About 49% of study participants had received two doses of any COVID-19 vaccine, while the other half had already received the booster dose [**Table 1**].

Table 1. Sociodemographic characteristics of the study participants (n=302)

Variable		N (%)
Mean age (±S.D.) in years		**28.9 (8.3)**
Sex	Male	147 (48.7)
	Female	155 (51.3)
Age group	18-29 years	185 (61.3)
	30-39 years	75 (24.8)
	40 and above	42 (13.9)
Employment	Doctors	33 (10.9)
	Nurses	81 (26.8)
	Laboratory technicians	12 (4)
	MBBS students	67 (22.2)
	Ancillary staff	92 (30.5)
	Others	17 (5.6)
Department	Clinical	164 (54.3)
	Pre/para-clinical	138 (45.7)
Vaccine received	Covishield	222 (73.5)
	Covaxin	49 (16.2)
	Sputnik	1 (0.3)
	Don't know	30 (9.9)
	1st dose	5 (1.7)
	2nd dose	148 (49)
Last dose received	Booster dose	149 (49.3)

One in four participants had suffered from COVID-19 in the past. A year had elapsed since the last infection in those who tested positive for COVID-19. One in twenty COVID-positive participants reported suffering from any sequelae [**Table 2**]. Seven out of ten participants were willing to take an additional vaccine booster [**Figure 1**].

Table 2. History of COVID-19 infection and its sequelae among the participants

COVID-19 infection history	N (%)
Yes	82 (27.2)
No	220 (72.8)
Time elapsed (in months) since last infection (IQR)	12 (10-20)
Any sequelae of COVID-19 infection	
Yes	5 (6.1)
Respiratory problems	3 (1)
Anosmia	1 (0.3)
Hair loss	1 (0.3)
None	77 (25.5)

Figure 1. Participants willing to receive COVID-19 vaccine booster

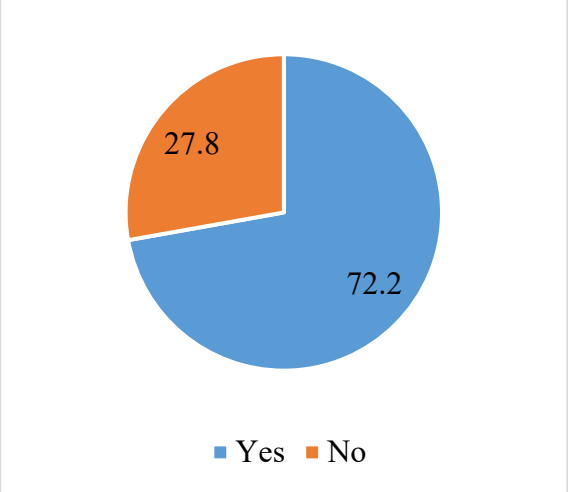

Table 3 shows the factors affecting the participants' willingness to uptake any COVID-19 vaccine booster. Being a healthcare worker and working in non-clinical department was significantly associated with booster acceptance. Age, sex, history of COVID-19 infection, type of vaccine and number of doses of vaccine received did not affect the willingness to receive a booster dose.

Table 3. Factors affecting the participants' willingness for COVID-19 vaccine booster

Variable	Willing for a vaccine booster			Chi-square (P value)
	Yes N (%)	No N (%)	Total N (%)	
Total Participants	**218 (72.2)**	**84 (27.8)**	**302 (100)**	-
Sex				
Male	99 (45.4)	48 (57.1)	147 (48.7)	3.34 (0.07)
Female	119 (54.6)	36 (42.9)	155 (51.3)	
Age group				
18-29 years	133 (61)	52 (61.9)	185 (61.3)	2.27 (0.32)
30-39 years	51 (23.4)	24 (28.6)	75 (24.8)	
40 and above	34 (15.6)	8 (9.5)	42 (13.9)	
Employment				
Health care workers	100 (45.9)	26 (31)	126 (41.7)	6.57 (0.04)
Ancillary staff	76 (34.9)	33 (39.3)	109 (36.1)	
Students	42 (19.3)	25 (29.8)	67 (22.2)	
Department				
Clinical	104 (47.7)	60 (71.4)	164 (54.3)	13.75 (0.0002)
Non-clinical	114 (52.3)	24 (28.6)	138 (45.7)	
Vaccine received				
Covishield	156 (71.6)	66 (78.6)	222 (73.5)	5.68 (0.06)
Covaxin	34 (15.6)	15 (17.9)	49 (16.2)	
Don't know/Others	28 (12.8)	3 (3.6)	31 (10.3)	
Last dose received				
1st dose	2 (0.9)	3 (3.6)	5 (1.7)	5.34 (0.07)
2nd dose	114 (52.3)	34 (40.5)	148 (49)	
Booster dose	102 (46.8)	47 (56)	149 (49.3)	
History of COVID-19				
Yes	58 (26.6)	24 (28.6)	82 (27.2)	0.12 (0.73)
No	160 (73.4)	60 (71.4)	220 (72.8)	
Sequelae of COVID-19				
Yes	2 (3.3)	3 (13.6)	5 (6.1)	2.98 (0.08)
No	58 (96.7)	19 (86.4)	77 (93.9)	

Table 4 presents the reasons given for the acceptance or rejection of the COVID-19 vaccine booster by the participants. The main reason for booster dose uptake was perceiving the vaccine as an immunity booster, followed by a recent rise in COVID-19 cases. Most of the participants did not state any preference towards any specific vaccine. One-fourth of them preferred injectable vaccines, while about 15.1% expressed a preference for nasal vaccines. Out of 84 unwilling participants, most did not perceive the need for further vaccination (57.1%) and had experienced side effects (20.6%) after vaccination.

Table 4. Reasons given for acceptance or rejection of COVID-19 vaccine boosters

Variable	N (%)
Willing for a vaccine booster	218 (72.2)
Reasons for willingness for the booster dose	185 (84.9)
Recent rise in COVID-19 cases	67 (36.2)
Missed the booster dose earlier	21 (11.4)
As an immunity booster	97 (52.4)
Preference for any specific route of administration	
No	128 (58.7)
Yes	90 (41.3)
Reasons for preferring the injectable booster vaccine	57 (26.2)
Safe and effective vaccine	23 (40.4)
Available free of cost	4 (7)
Good experience in the past	24 (42.1)
Easily available	6 (10.5)

Variable	N (%)
Reasons for preferring the nasal booster vaccine	33 (15.1)
Convenience of administration	21 (63.6)
Fear of injection	2 (6.1)
Previous side effects with injectable vaccine	6 (18.2)
Injectable vaccine is contraindicated	4 (12.1)
Not willing for a vaccine booster	84 (27.8)
Reasons for non-acceptance of vaccine booster	63 (75)
Do not perceive the need for further vaccination	36 (57.1)
Experienced side effects after COVID vaccine	13 (20.6)
Already received three doses of the vaccine	7 (9.5)
Same vaccine is not available (Covaxin/ Sputnik)	3 (4.8)
Do not consider COVID-19 a risk anymore	2 (3.2)
Others	3 (4.8)

DISCUSSION

The study explored the reasons responsible for the uptake of booster doses and preference for the route of administration of the COVID-19 vaccine. Additionally, the survey provided information on reasons given by participants who were unwilling to take up booster doses. We observed a high coverage of primary doses (100%), secondary doses (98.3%), and booster doses (49.3%) of COVID-19 vaccines among the participants. They showed a high willingness for a COVID-19 vaccine booster. Perception of the vaccine as an immunity booster emerged as a crucial factor for booster acceptance. Most participants had received Covishield (73.5%) followed by Covaxin (16.2%). The state of Himachal Pradesh received more doses of the Covishield than Covaxin from the Central Government which may have led to greater administration of Covishield vaccine. Other studies have reported similar findings where uptake of Covishield was greater than Covaxin among healthcare workers.(12,13)

The vaccine booster acceptance in our study was higher compared to a recent pan-India survey (60%).(14) High booster vaccine intention has been reported in other countries like China (90.3%) and the USA (83.6%), while similar intention has been reported among healthcare workers in Czechia (71.3%) and the UAE (70.2%).(9,11,15,16) Half of the participants in our study had already taken a vaccine booster compared to 62.2% of healthcare professionals in the pan-India survey. Another cross-sectional study conducted among adults aged 50 years and above in Delhi found that 58.3% of participants had received a COVID-19 booster dose.(8) This difference can be attributed to the difference in the period of these studies. Our study was conducted during winter, amidst a rise in global COVID-19 cases, highlighting participants' felt need for booster doses. Sharma et al surveyed during the winter-spring season, which may explain the increase in the proportion of adults receiving COVID-19 booster shots.(8) The pan-India survey was conducted a little later in the summer when the COVID-19 cases had declined, which might have contributed to low willingness for booster doses.

The majority of the participants considered the vaccine as an immunity booster. The booster shot may complement the vaccine-induced immunity established by the primary series of vaccines. Over one-third of the participants considered the recent rise in COVID-19 cases responsible for their willingness for booster doses. Padhi et al observed that HCWs with high-risk perception of infection were more likely to accept the COVID-19 vaccines over time.(3) Most willing participants did not prefer any specific vaccine as a booster. The existing guidelines recommend using the homologous vaccine as a booster dose after nine months of the second dose.(7) Rose et al. observed that homologous and heterologous booster vaccination with Covishield or Covaxin in individuals who had received two doses of homologous Covishield or Covaxin were found safe and immunogenic.(17) In Covaxin-primed individuals, a heterologous boost with Covishield offers a better immune response than a homologous boost. However, interchanging of the vaccines was not allowed under the National COVID Vaccination Program.

Adverse events following vaccination can negatively impact a person's intention to receive the vaccine. Fan et al. reported that over half of the participants who were hesitant to uptake booster shots had expressed concern about adverse events of the booster dose.(15) One-fifth of the unwilling participants in our study had experienced side effects after previous COVID-19 vaccination. Given a choice, one in ten participants preferred a nasal vaccine due to its convenient administration. Nasal vaccines induce IgA antibodies in the respiratory secretions and provide sterilizing immunity at the site of infection.(18) Slamanig et al found that the intranasal Omicron variant vaccine induces high mucosal IgA, serum IgG, memory B cells, and local T

cell responses in the lungs of female mice.(19) On the other hand, the injectable booster induces limited mucosal immunity. The injectable mRNA vaccine booster doses promote the SARS-Cov-2 neutralizing antibody in the nasal secretion that may potentially prevent the infection.(20) This highlights the need to further study the mechanism of mucosal immunity in humans. Recently, a novel nasal vaccine has been tested for safety and effectiveness against COVID-19 in the USA.(21)

The vaccines tailored to the emerging SARS-CoV-2 variants provide a ray of hope in the current scenario. In 2023, the United States Food and Drug Administration approved the replacement of bivalent vaccines containing ancestral strains with monovalent COVID-19 vaccines. The XBB.1.5 mRNA monovalent booster induced serum neutralizing antibody production against Omicron variants, including XBB.1 and JN1.(22,23) Recently, the US FDA approved two updated mRNA vaccines effective against the circulating Omicron KP.2 strains.(24) Centre for Disease Control recommended additional doses of the 2024-25 COVID-19 vaccine for everyone aged 6 months or older to protect themselves against currently circulating variants.(25) India has not issued any recommendations for COVID-19 booster vaccination after 2023.

Conclusion

Knowledge about the reasons for willingness for COVID-19 vaccine booster and alternative routes of vaccine administration may increase the readiness of the HCWs for additional doses. Further research is required to explore the attitudes and practices along with an awareness campaign to motivate people to uptake booster doses.

Recommendation

In the dynamic landscape of SARS-CoV-2 variants, the solution may rest with continuously updating the vaccines against the emerging strains and vaccination of high-risk individuals with booster vaccines.

Limitation of the Study

The questionnaire was self-administered by the participants which may lead to self-reporting bias. The data regarding risk factors (smoking, alcohol intake) and comorbidities (hypertension, diabetes, chronic diseases) was not collected from the participants. An ongoing global surge in COVID-19 cases and the detection of the Omicron variant in the country during the data collection period might have affected the willingness for booster doses. Repeated cross-sectional surveys or studies with longer duration may provide a better evidence.

Relevance of the Study

Healthcare workers has an important role in moulding the public perception of vaccine booster and helping policymakers to make targeted strategies to promote uptake. The nasal vaccine may provide an alternative for booster-hesitant individuals.

Authors Contribution

MT conceived the study concept and design, finalized the study concept and approved the manuscript. NS helped finalize the study concept, collected and analyzed the data, and drafted the manuscript. SK helped with data collection, assisted in data analysis, and writing the manuscript.

Financial Support and Sponsorship

Nil

Conflict of Interest

There are no conflicts of interest.

Declaration of Generative AI and AI Assisted Technologies in the Writing Process

The authors haven't used any generative AI/AI assisted technologies in the writing process.

References

1. Ministry of Health and Family Welfare. Press Statement by the Drugs Controller General of India (DCGI) on Restricted Emergency approval of COVID-19 virus vaccine [Internet]. Press Information Bureau. 2021 [cited 2025 Aug 25]. Available from: https://pib.gov.in/PressReleseDetail.aspx?PRID=1685761
2. Government of India. PM Launches pan India rollout of COVID-19 vaccination drive [Internet]. Press Information Bureau. 2021 [cited 2025 Aug 25]. Available from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1689021
3. Padhi BK, Chakrapani V, Gupta M, Sharma N, Patro BK, Kar SS, et al. Trends in willingness to receive COVID-19 vaccines among healthcare workers in India: Findings from repeated cross-sectional national surveys. Front Public Heal. 2022;10:994206.
4. Chakraborti S, Gill J, Goswami R, Kumar S, Chandele A, Sharma A. Structural Profiles of SARS-CoV-2 Variants in India. Curr Microbiol. 2023;80(1):1.
5. Selvavinayagam ST, Yong YK, Joseph N, Hemashree K, Tan HY, Zhang Y, et al. Low SARS-CoV-2 viral load among vaccinated individuals infected with Delta B.1.617.2 and Omicron BA.1.1.529 but not with Omicron BA.1.1 and BA.2 variants. Front Public Heal. 2022;10:1018399.
6. World Health Organization. Interim statement on the use of additional booster doses of Emergency Use Listed mRNA vaccines against COVID-19 [Internet]. 2022 [cited 2025 Aug 25]. Available from: https://www.who.int/news/item/17-05-2022-interim-statement-on-the-use-of-additional-booster-doses-of-emergency-use-listed-mrna-vaccines-against-covid-19

7. Ministry of Health and Family Welfare. Guidelines for COVID-19 vaccination of children between 15-18 years and precaution dose to HCWs, FLWs & 60+ population with comorbidities. 2022.
8. Sharma N, Basu S, Lalwani H, Rao S, Malik M, Garg S, et al. COVID-19 Booster Dose Coverage and Hesitancy among Older Adults in an Urban Slum and Resettlement Colony in Delhi, India. Vaccines. 2023;11(7):1177.
9. Klugar M, Riad A, Mohanan L, Pokorná A. COVID-19 vaccine booster hesitancy (VBH) of healthcare workers in czechia: National cross-sectional study. Vaccines. 2021 Dec 1;9(12):1437.
10. Alhasan K, Aljamaan F, Temsah MH, Alshahrani F, Bassrawi R, Alhaboob A, et al. COVID-19 Delta Variant: Perceptions, Worries, and Vaccine-Booster Acceptability among Healthcare Workers. Healthcare. 2021;9(11):20.
11. Yadete T, Batra K, Netski DM, Antonio S, Patros MJ, Bester JC. Assessing Acceptability of COVID-19 Vaccine Booster Dose among Adult Americans: A Cross-Sectional Study. Vaccines. 2021;9(12):1424.
12. Rahi M, Yadav CP, Ahmad SS, Nitika, Das P, Sharma S, et al. Vaccination coverage and breakthrough infections of COVID-19 during the second wave among staff of selected medical institutions in India. PLOS Glob Public Heal. 2023;3(4):e0000946.
13. Tyagi K, Ghosh A, Nair D, Dutta K, Singh Bhandari P, Ahmed Ansari I, et al. Breakthrough COVID19 infections after vaccinations in healthcare and other workers in a chronic care medical facility in New Delhi, India. Diabetes Metab Syndr. 2021;15(3):1007.
14. Krishna E, Karthikeyan V, Ahmad S, Ranjan A, KM AH, Pandey S, et al. Acceptance of Annual Booster Doses of COVID-19 Vaccines Among Indian Healthcare Professionals: A Pan-India Cross-Sectional Survey. Cureus. 2023;15(11):e49363.
15. Wu F, Yuan Y, Deng Z, Yin D, Shen Q, Zeng J, et al. Acceptance of COVID-19 booster vaccination based on the protection motivation theory: A cross-sectional study in China. J Med Virol. 2022;94(9):4115.
16. Jairoun AA, Al-Hemyari SS, El-Dahiyat F, Jairoun M, Shahwan M, Al Ani M, et al. Assessing public knowledge, attitudes and determinants of third COVID-19 vaccine booster dose acceptance: current scenario and future perspectives. J Pharm Policy Pract. 2022 15(1):1–13.
17. Rose W, Raju R, Babji S, George A, Madhavan R, Leander Xavier JV, et al. Immunogenicity and safety of homologous and heterologous booster vaccination of ChAdOx1 nCoV-19 (COVISHIELD™) and BBV152 (COVAXIN®): a non-inferiority phase 4, participant and observer-blinded, randomised study. Lancet Reg Health Southeast Asia. 2023;12:100141.
18. Focosi D, Maggi F, Casadevall A. Mucosal Vaccines, Sterilizing Immunity, and the Future of SARS-CoV-2 Virulence. Viruses. 2022;14(2):187.
19. Slamanig S, González-Domínguez I, Chang LA, Lemus N, Lai TY, Martínez JL, et al. Intranasal SARS-CoV-2 Omicron variant vaccines elicit humoral and cellular mucosal immunity in female mice. EBioMedicine. 2024;105:105185.
20. Declercq J, Gerlo S, Van Nevel S, De Ruyck N, Holtappels G, Delesie L, et al. Repeated COVID-19 mRNA-based vaccination contributes to SARS-CoV-2 neutralizing antibody responses in the mucosa. Sci Transl Med. 2024;16(770):eadn2364.
21. Harris E. NIH Starts Testing Nasal COVID-19 Vaccine in US. JAMA. 2024;332(8):610–610.
22. Lasrado N, Rowe M, McMahan K, Hachmann NP, Miller J, Jacob-Dolan C, et al. SARS-CoV-2 XBB.1.5 mRNA Booster Vaccination Elicits Limited Mucosal Immunity. Sci Transl Med. 2024;16(770):eadp8920.
23. Wang Q, Guo Y, Bowen A, Mellis IA, Valdez R, Gherasim C, et al. XBB.1.5 monovalent mRNA vaccine booster elicits robust neutralizing antibodies against XBB subvariants and JN.1. Cell Host Microbe. 2024;32(3):315.
24. Anderer S. FDA Approves Updated COVID-19 Vaccines. JAMA. 2024;332(15):1228–1228.
25. Centers for Disease Control and Prevention. Staying Up to Date with COVID-19 Vaccines COVID-19 CDC [Internet]. 2025 [cited 2025 Aug 25]. Available from: https://www.cdc.gov/covid/vaccines/stay-up-to-date.html