



Phenotypic Characterization and Antimicrobial Susceptibility of Methicillin-Resistant *Staphylococcus aureus* Isolated from Wound Infections at District Headquarters Hospital, Okara

Aliya Rafique ¹, Dr. Samyia Abrar¹, Muhammad Umar ² and Faisal Khan ³

¹Department of Biological Sciences, Superior University Lahore, Lahore, Pakistan

²Institute of Microbiology, Government College University Faisalabad, Faisalabad, Pakistan

³Department of Health and Sciences, University of Northampton, Northamptonshire, United Kingdom

*Correspondence: umarmicro461@gmail.com, mumar.gcuf.edu.pk@gmail.com

ARTICLE INFO

ARTICLE HISTORY: CVJ-26-714

Received: 22 June 2026

Revised: 23 Aug 2026

Accepted: 25 Aug 2026

Published online: 27 Aug 2026

Key words:

Antimicrobial Resistance

Antimicrobial Susceptibility

Cefoxitin

MRSA

Staphylococcus aureus

Wound Infection

ABSTRACT

Wound infections can really mess up healing, leading to delayed recovery and longer clinical stay, and in particular *Staphylococcus aureus* is a frequent bacterial cause in wounds. Now, methicillin resistant *S. aureus* (MRSA) makes treatment harder, because it is resistant to β lactam antibiotics, so options get limited. In this work we looked at how often *S. aureus* showed up, what phenotypic traits it had, and what antimicrobials it actually responds to, from wound infections collected at District Headquarters Hospital, Okara. So, we did a kind of cross sectional, lab-based study on 50 wound swab specimens. Each sample was cultured on Nutrient Agar, Blood Agar, and Mannitol Salt Agar, and then incubated aerobically at 37°C for about 18–24 hours. Suspected *S. aureus* isolates were checked using colony appearance, Gram stain, catalase and coagulase tests. For antimicrobial susceptibility, the Kirby–Bauer disc diffusion method was used with 11 different antimicrobial agents. As for methicillin resistance, it was determined phenotypically with a 30 μ g cefoxitin disc. After that, the results were analyzed using descriptive statistics, an independent samples t test, and one way analysis of variance. Overall, *S. aureus* was recovered from 35 out of 50 wound swabs, which is 70%. Of the confirmed isolates, 21 (60%) were MRSA and 14 (40%) were MSSA. The patients were mostly male, (68%), and the 41–50 year age group provided the largest share of samples, around 26%. When it came to resistance, it was highest against ciprofloxacin (71.4%), erythromycin (68.6%), ampicillin (65.7%), and co trimoxazole (62.9%). Meanwhile, all isolates were susceptible to linezolid and vancomycin. Also, mean inhibition zone diameters showed a significant difference between MRSA and MSSA, (16.48 ± 2.41 vs 25.16 ± 2.08 mm, $t(33) = -11.03$, $P < 0.001$). In short, these findings show a noticeable MRSA burden, along with multiple drug resistance among wound linked *S. aureus*. Routine culture and antimicrobial susceptibility testing, plus antimicrobial stewardship programs and infection control measures, should be emphasized.

To Cite This Article: Rafique A, Abrar DS, Umar M and Khan F, 2026. phenotypic characterization and antimicrobial susceptibility of methicillin-resistant *Staphylococcus aureus* isolated from wound infections at district headquarters hospital, Okara. Continental Vet J, x(x): xxx <http://dx.doi.org/10.71081/cvj/2026.091>

INTRODUCTION

Wound infections, especially ones tied to *Staphylococcus aureus*, make things harder in clinic, because they tend to raise morbidity, stretch hospital time, and also drive healthcare expenses up. *S. aureus* is a Gram-positive pathogen, and it brings a stack of virulence tools, like cytolytic proteins plus immune evasion mechanisms, so it can set up shop when the skin barrier is compromised (KG

Kaapu et al., 2023); Linz et al., 2023). At the same time, the growth of antimicrobial resistance (AMR) really shifts the whole picture, and methicillin-resistant *S. aureus* (MRSA) is a big part of that, since these resistant strains show up a lot in healthcare settings (Babayev & Kurtoglu, 2025). Because of this, treatment options aren't just standard anymore. There are, however, newer strategies that sound promising, for example using palmitoleic acid in a way that can boost antibiotic uptake, and also ultrasound-mediated drug

delivery designed to push through biofilms. These routes might help counter those usual barriers. Overall, handling wound infections well takes a more complicated plan than one intervention, basically timed diagnosis, antimicrobial stewardship, and more advanced therapeutic modalities all together, so the effect of AMR is reduced and patient outcomes can improve (Virginie Papadopoulou et al., 2023; Babayev & Kurtoğlu, 2025).

Biofilm formation really mucks up the treatment of chronic wounds that are infected with methicillin-resistant *Staphylococcus aureus* MRSA, because those biofilms kind of shield bacterial cells from both antimicrobial agents, and from the hosts immune response (Virginie Papadopoulou et al., 2023; Elmanama et al., 2020). The *mecA* gene encodes an altered penicillin-binding protein, called PBP2a, and it sits right at the center of how MRSA stays resistant to β -lactam antibiotics, since cell wall synthesis can continue even while these drugs are around. A number of studies suggest that many biofilm-producing *S. aureus* strains are also multidrug-resistant too, and biofilm formation is pretty much a major ingredient in why these infections can persist (Elmanama et al., 2020). Newer ideas, like using palmitoleic acid to boost antibiotic uptake, plus ultrasound assisted delivery of medicines, have been promising when it comes to jumping over these barriers, and increasing the effectiveness of treatments targeting MRSA biofilms (Virginie Papadopoulou et al., 2023; C, 2025). Figuring out these processes is key for designing therapeutic approaches that actually work, for managing MRSA infections in chronic wounds (C, 2025).

Methicillin-resistant *Staphylococcus aureus* (MRSA) is kind of a big pathogen thing, it causes serious infections in healthcare, and also outside, in the community, especially skin and soft tissue infections SSTIs. The way it spreads and who gets it is influenced by antimicrobial exposure, infection control procedures, and how patients move back and forth between hospital life and everyday life (Turner et al., 2019). The Kirby–Bauer disc diffusion approach, and more specifically using cefoxitin, is pretty essential for catching MRSA in a phenotypic way, because it points to methicillin resistance fairly clearly. A lot of studies suggest MRSA shows strong resistance to many routine antibiotics, while still being notably susceptible to vancomycin (Akram et al., 2025; Duraisamy et al., 2020). Also, community-associated MRSA (CA-MRSA) strains have come up they are not the same as healthcare-associated strains, so it really highlights the need for careful ongoing surveillance and strong infection control measures, to reduce the growing MRSA threat in both places.

Molecular diagnostic approaches definitely help a lot with understanding how resistance mechanisms work, and also how epidemiological ties show up across infectious diseases, but in the real world their use is still often held back in healthcare settings with limited resources, so people end up leaning on conventional culture and susceptibility testing, again and again. Even though molecular techniques like PCR and next-generation sequencing can give quick detection, and also sensitive reads of pathogens plus their resistance genes, they also need a lot of setups infrastructure, hands-on technical know-how and serious financial investment. And that whole package may not be practical in low-resource environments (Aldea et al., 2025; Okeke & Ihekweazu, 2021). On the other side, traditional culture methods, while

slower and not as sensitive, still matter a great deal for local surveillance and outbreak response, especially for organisms such as *Salmonella* and *Neisseria gonorrhoeae*, where correct identification of resistance is basically the key for proper treatment decisions and public health actions (Sophian, 2025). So really, using a combined approach, meaning both molecular and conventional strategies together, is what's usually recommended to improve diagnostic precision, and strengthen antimicrobial stewardship across different healthcare settings (Islam, 2025).

Pakistan is dealing with big issues tied to antimicrobial resistance AMR, especially when it comes to methicillin-resistant *Staphylococcus aureus* MRSA. This one is a real danger in healthcare spaces, it keeps showing up in hospitals and clinic wards. Lots of studies report a very high prevalence of MRSA, and the resistance rates can go beyond 80% against usual drugs like penicillin and cefoxitin (Iqbal et al., 2022; Farmanullah et al., 2025). What stands out is that local, nearby surveillance matters, because district level hospitals do not always match the resistance behavior seen in tertiary-care facilities, so monitoring should be adjusted not copied. On top of that, antibiotic consumption climbed about 65% from 2000 to 2015, and this rise paired with careless or unsuitable prescribing practices, pushes the whole AMR situation further into trouble (Osama et al., 2025). Also, the systematic review on antibiotic resistance across Pakistan suggests MRSA is found in many kinds of clinical specimens, meaning immediate steps are required to strengthen infection control and to promote sensible antibiotic use (Akram et al., 2025; Bilal et al., 2021).

The study that was done at District Headquarters Hospital, Okara was mostly about trying to describe *Staphylococcus aureus* isolates that came from wound infections, like what's the situation with methicillin-resistant *Staphylococcus aureus* (MRSA) and how they respond to different antimicrobials. In the end, the results really pointed to MRSA as a major issue, and there are reports that say a large portion of *S. aureus* isolates taken from wound samples show resistance to several antibiotics, including penicillin along with erythromycin, yet they tend to stay susceptible to vancomycin and linezolid, (Khan et al., 2025; Repati Gowri et al., 2024). For confirming MRSA presence, phenotypic detection approaches were used, for example cefoxitin disc diffusion, so it feels like the local evidence really matters when clinicians decide the first line therapy and also how infection control should be done in practice. Overall, this work highlights that surveillance shouldn't stop, and antibiotic use has to stay rational, otherwise the resistance trends that are being seen in clinical areas could keep getting worse (Khan et al., 2025).

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional laboratory-based study was conducted among patients presenting with wound infections at District Headquarters Hospital, Okara. A total of 50 wound swab specimens were collected for microbiological examination.

Sample Collection

Wound specimens were gathered with sterile swabs, using aseptic conditions for real. Before any lab work started each specimen got an identification code so it was actually tracked. After that, the samples were moved pretty quickly to the microbiology lab for culturing and then identification. The people who had taken systemic antibiotics in the prior 48 hours were not included, because of that. Also, any improperly labelled samples, the ones that leaked, got contaminated, or were basically repeats, were left out too depending on what the study required.

Bacterial Isolation

Wound swabs got inoculated onto Nutrient Agar, and Blood Agar. Mannitol Salt Agar was additionally used for selective isolation and to check for mannitol fermentation, in a kind of more specific way. The inoculated plates were then incubated aerobically at 37°C for about 18–24 hours. After that, colonies were looked at based on morphology, pigmentation, hemolysis, and their growth characteristics, kind of overall behavior. A few representative colonies were purified prior to biochemical work, and antimicrobial testing.

Identification of *S. aureus*

Presumptive colonies were examined microscopically following Gram staining. Gram-positive cocci arranged in clusters were considered consistent with *Staphylococcus* species. Catalase and coagulase tests were subsequently performed. Catalase positivity was indicated by immediate bubble formation following exposure to hydrogen peroxide. Coagulase positivity was indicated by visible agglutination. The combined cultural, microscopic, and biochemical characteristics were used to confirm *S. aureus*.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was performed using the Kirby–Bauer disc diffusion method. A standardized bacterial suspension equivalent to a 0.5 McFarland standard was prepared. The suspension was inoculated uniformly onto Mueller–Hinton Agar. Antimicrobial discs were applied to the inoculated surface. Plates were incubated at 37°C for 18–24 hours.

The following antimicrobial agents were evaluated:

Table 2.1: List of Antibiotics Tested Against Gram-Positive Bacteria

Sr. No.	Antibiotic	Abbreviation	Class	Disc Potency
1	Ciprofloxacin	CIP	Fluoroquinolone	5 µg
2	Clindamycin	DA	Lincosamide	2 µg
3	Co-trimoxazole	SXT	Folate pathway inhibitor	25 µg
4	Erythromycin	E	Macrolide	15 µg
5	Ampicillin	AMP	Penicillin	10 µg
6	Gentamicin	CN	Aminoglycoside	10 µg
7	Penicillin G	P	Penicillin	10 µg
8	Cefoxitin	FOX	Cephameycin	30 µg
9	Linezolid	LZD	Oxazolidinone	30 µg
10	Vancomycin	VAN	Glycopeptide	30 µg
11	Amoxicillin-Clavulanic acid	AMC	β-lactam/β-lactamase inhibitor	10 µg

Phenotypic Detection of MRSA

Methicillin resistance was assessed using a 30-µg cefoxitin disc. Isolates demonstrating cefoxitin resistance were classified as MRSA. Isolates without the corresponding

resistant phenotype were classified as MSSA. The reports 21 cefoxitin-resistant isolates and 14 cefoxitin-sensitive isolates among the 35 confirmed *S. aureus*.

Statistical Analysis

Data were analyzed using descriptive statistics. Frequencies and percentages were calculated for categorical variables. An independent-samples *t*-test was used to compare mean inhibition-zone diameters between MRSA and MSSA isolates. One-way ANOVA was used to compare mean inhibition-zone diameters among the tested antimicrobial agents. A *p* value below 0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

A total of 50 wound swab specimens were examined. 34 samples (68%) were obtained from male patients and 16 (32%) from female patients.

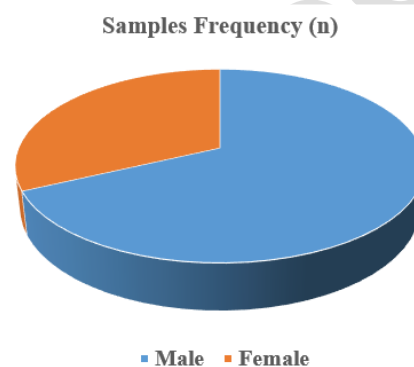


Fig. 1: Demographic distribution of patients with wound infections according to sex.

Age Distribution

Participants represented eight age groups between 0 and 80 years. The largest proportion occurred in the 41–50-year group. The 41–50-year group contributed 13 cases (26%), representing the largest age category. The 0–10-year and 71–80-year groups each contributed 2 cases (4%).

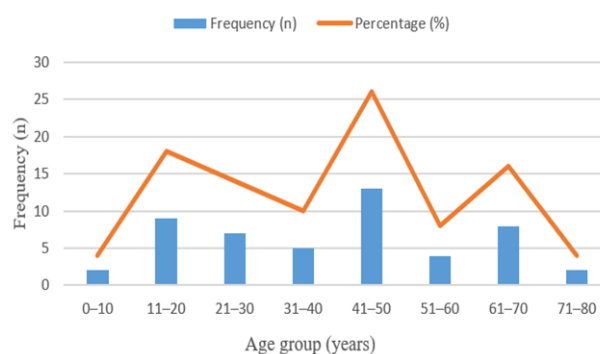


Fig. 2: Demographic distribution of patients with wound infections according to age group.

Isolation of *S. aureus*

Of the 50 wound swabs, 35 (70%) yielded characteristic *S. aureus*. The remaining 15 specimens (30%) did not yield confirmed *S. aureus*.

Table 3.1: Isolation of *S. Aureus* from Wound Swabs

Culture result	Frequency (n)	Percentage (%)
<i>S. aureus</i> positive	35	70
<i>S. aureus</i> negative	15	30
Total	50	100

Cultural and Biochemical Characteristics

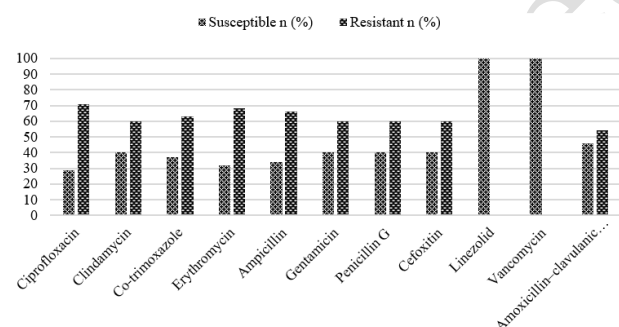
Growth on Mannitol Salt Agar produced smooth, circular, golden-yellow colonies with yellow coloration of the surrounding medium. This reaction was consistent with mannitol fermentation. Gram staining showed Gram-positive cocci arranged in grape-like clusters. All 35 confirmed isolates were catalase positive and coagulase positive. The remaining 15 samples were negative for both identification reactions.

Table 3.2: Phenotypic Characteristics of Confirmed *S. Aureus* Isolates

Characteristic	Observation
Nutrient Agar	Smooth, circular, convex, creamy to golden-yellow colonies
Blood Agar	Smooth colonies with β -hemolysis
Mannitol Salt Agar	Yellow colonies with yellow surrounding medium
Gram reaction	Gram-positive
Cell morphology	Cocci
Arrangement	Grape-like clusters
Catalase	Positive
Coagulase	Positive

Antimicrobial Susceptibility Pattern

All 35 confirmed *S. aureus* isolates were tested against 11 antimicrobial agents. Linezolid and vancomycin showed complete susceptibility. Ciprofloxacin showed the highest resistance at 71.4%, followed by erythromycin at 68.6%, ampicillin at 65.7%, and co-trimoxazole at 62.9%. Resistance to clindamycin, gentamicin, penicillin G, and cefoxitin was 60%. Amoxicillin-clavulanic acid showed 54.3% resistance.

**Fig. 3:** Antimicrobial resistance profile of *Staphylococcus aureus* isolates against 11 tested antimicrobial agents.

Phenotypic MRSA Prevalence

Among the 35 confirmed *S. aureus* isolates, 21 (60%) were resistant to cefoxitin and classified as MRSA. Fourteen isolates (40%) were cefoxitin susceptible and classified as MSSA.

Table 3.4: Distribution of MRSA and MSSA Isolates

Isolate	n	%
MRSA	21	60
MSSA	14	40
Total	35	100

Inhibition-Zone Descriptive Statistics

Linezolid produced the largest mean inhibition zone at 28.49 ± 1.27 mm. Vancomycin produced a mean zone of 20.34 ± 0.96 mm. Ciprofloxacin had a mean inhibition zone of 16.54 ± 5.82 mm. Erythromycin showed a mean zone of 17.46 ± 5.68 mm.

Table 3.5: Descriptive Statistics of Inhibition-Zone Diameters

Antibiotic	Mean (mm)	SD	Variance	Minimum	Maximum
Ciprofloxacin	16.54	5.82	33.87	11	28
Clindamycin	19.43	4.96	24.60	14	28
Co-trimoxazole	18.77	5.11	26.11	12	28
Erythromycin	17.46	5.68	32.26	10	29
Ampicillin	17.91	5.32	28.30	11	28
Gentamicin	20.03	4.58	20.98	15	29
Penicillin G	18.97	5.03	25.30	12	29
Cefoxitin	19.34	5.21	27.14	15	30
Linezolid	28.49	1.27	1.61	26	31
Vancomycin	20.34	0.96	0.92	18	22
Amoxicillin-clavulanic acid	20.77	4.41	19.45	17	29

Comparison Between MRSA and MSSA

The mean inhibition-zone diameter was 16.48 ± 2.41 mm for MRSA isolates and 25.16 ± 2.08 mm for MSSA isolates. The independent-samples *t*-test demonstrated a statistically significant difference between the two groups ($t(33) = -11.03$, $P < 0.001$).

Table 3.6: Comparison of Mean Inhibition-Zone Diameters Between MRSA and MSSA

Group	n	Mean (mm)	SD
MRSA	21	16.48	2.41
MSSA	14	25.16	2.08

3.9 One-Way ANOVA

One-way ANOVA was used to compare mean inhibition-zone diameters among the 11 tested antimicrobial agents. The thesis reports a statistically significant difference in antimicrobial activity ($P < 0.001$).

Statistical analysis	Result	Interpretation
Independent-samples <i>t</i> -test	$t(33) = -11.03$, $P < 0.001$	MRSA and MSSA differed significantly
One-way ANOVA	$P < 0.001$	Mean inhibition zones differed significantly among tested antibiotics

DISCUSSION

The present study recovered *S. aureus* from 35 of 50 wound specimens, giving a recovery rate that comes to 70%. From this it looks pretty clear that *S. aureus* really stands out among wound associated bacterial infections within the study population. The organism was identified by mixing cultural observations, microscopic features and biochemical characteristics, kind of together rather than in steps alone. With this way of working the identification stayed steady across the confirmed isolates (Yahaya, 2023). On Nutrient Agar the colonies showed typical morphology while Blood Agar revealed β -haemolysis, and on Mannitol Salt Agar there was mannitol fermentation. Gram staining also showed Gram-positive cocci arranged in clusters, which fits well with the expected pattern.

Finally, all confirmed isolates were catalase positive and coagulase positive too. Overall, these results back up the routine use of conventional microbiological methods, for identifying *S. aureus* in clinical laboratories (Habibović et al., 2024).

The demographic breakdown showed that males made up 68% of the study population. In the thesis discussion, this apparent predominance is linked to higher exposure to trauma, workplace dangers, outdoor activities, and even contaminated surroundings. The 41–50 year age bracket had the largest share of patients, (Adetunji & Obeng-Gyasi, 2024). The thesis also implies that work-related contact, long standing illnesses, surgical or operative procedures, along with things that influence tissue repair and wound healing, may be part of why infections show up more in middle-aged adults. That said, this present study did not directly measure those risk factors. So, all of those points should be taken as plausible contributors rather than as proven or demonstrated associations. Overall, the main result was the 60% MRSA prevalence among the confirmed *S. aureus* isolates. Specifically, 21 of the 35 isolates were resistant to cefoxitin, and were therefore classified as MRSA (“Epidemiological Characteristics of 6930 Emergency Trauma Patients in Guangming District, Shenzhen,” 2024).

The prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) in Pakistani healthcare settings looks really alarmingly high, and multiple studies suggest that resistance levels are strong enough to squeeze the available treatment options. For example, one study said about 66.7% of MRSA strains were isolated from surgical units, and the same report showed resistance to widely used antibiotics, including ciprofloxacin (71.4%), erythromycin (68.6%) and ampicillin (65.7%) (Hussain et al., 2019). In another investigation, 58.1% of *Staphylococcus aureus* isolates turned out to be MRSA, plus there was high resistance to ciprofloxacin (25.6%) and erythromycin (24.4%) (Aqsa Aslam et al., 2022). Then, at Khyber Teaching Hospital, the MRSA prevalence was reported as 23.05%, while ciprofloxacin resistance rose to 84.45% which is striking. Taken together, all these results really point toward a critical requirement for stronger surveillance, as well as tighter infection control practices, so Pakistan can slow down both the increasing MRSA frequency and the resistance profiles that come along with it (Perveen, 2013).

This multi drug resistant phenotype creates some real difficulties for empirical treatment, in the sense that the usual initial antibiotic choice can go sideways. The findings also back up the idea of using culture and susceptibility testing before picking any antibiotic, whenever it is clinically feasible. The high resistance to ciprofloxacin is especially notable, since fluoroquinolones are used a lot in routine practice. With repeated antimicrobial exposure, there is selective pressure that tends to favour resistant bacterial populations over time. Still, the current study did not look at the individual antibiotic exposure histories for each participant. So, antibiotic misuse cannot be directly proven as the reason behind the resistance in these isolates. Meanwhile, linezolid and vancomycin showed complete susceptibility among the isolates that were tested. Overall, this suggests that these agents still keep in-vitro activity against the study isolates. The thesis also mentions strong

effectiveness of these drugs against *S. aureus* (Sadat & Ahani Azari, 2020).

Not seeing any resistance to linezolid and vancomycin is kind of clinically reassuring, at least that part is clear. Still, these agents should not be used in a random way, like just in case. Instead, their use needs to be locked to clinical reasons, susceptibility testing, and general antimicrobial stewardship ideas. When we compared MRSA versus MSSA, there was a noticeable gap in the inhibition-zone diameters. MRSA had a mean diameter of 16.48 ± 2.41 mm, while MSSA came out 25.16 ± 2.08 mm. The gap was statistically significant ($P < 0.001$). So, this gives more solid quantitative support for the reduced antimicrobial effect we saw in the MRSA isolates. Also, the one-way ANOVA showed significant differences across the antimicrobial agents. Linezolid ended up with the largest mean inhibition zone, and ciprofloxacin had one of the smallest mean zones, kind of consistent with what we'd expect. Overall, these patterns line up with the resistance proportions we observed in the susceptibility analysis.

This study has some limitations, so you have to be careful when looking at the results. For starters, we only examined 50 wound specimens, which is kind of small. Also, the work was done in just one healthcare setting, so the context might be a little narrow. On top of that, patient-level risk factors were not really assessed in a comprehensive manner, so some covariates could have been missed. And importantly, molecular characterization of resistance determinants was not carried out. So, overall, these findings should be seen as local surveillance data, not as a fully representative estimate for the larger population across Pakistan (Asghar et al., 2025).

Conclusions

The study showed a real, substantial burden of *S. aureus* among the wound specimens. Actually, *S. aureus* was recovered from about 70% of all examined samples. Phenotypic MRSA made up close to 60% of the confirmed *S. aureus* isolates, so yeah, more than half in a way. When we looked at the drug profiles, high resistance showed up against ciprofloxacin, erythromycin ampicillin, co-trimoxazole, clindamycin, gentamicin, penicillin G and cefoxitin. At the same time, all the tested isolates stayed susceptible to linezolid and vancomycin, which is kind of reassuring. Also, the significant difference between MRSA and MSSA inhibition-zone diameters really supports that MRSA isolates carry a more resistant phenotype, not just a small shift. Overall, these findings underline the need for routine culture and antimicrobial susceptibility testing in wound infections. Antimicrobial therapy should be guided by the susceptibility results whenever it's possible to do so, rather than guessing. Regular MRSA surveillance and solid infection-control measures are also required, not optional. For future work, investigations should include molecular detection of resistance determinants, to back up and confirm the genetic basis behind phenotypic methicillin resistance.

DECLARATION

Funding: No external funds were provided for this study by a national or international funding agency.

Acknowledgements: The authors acknowledge the cooperation of the patients who participated in the study and the laboratory personnel who assisted with specimen processing and microbiological investigations.

Data Availability: All the data supporting the findings of this study are included in this manuscript.

Ethics Statement: Ethical approval for the study was obtained through the institutional Ethics Review Committee before commencement of the research. The thesis identifies an Ethics Review Committee comprising a convener and committee members. Written informed consent was obtained from patients or their legal guardians before specimen collection. Patient information was kept confidential throughout the study.

Conflict of Interest: The authors declare that they have no conflict of interest related to this study, its findings, or the publication of this manuscript.

Author's Contribution: Aliya Rafique conducted the research study, including sample collection, experimental work, data collection, and laboratory investigations. Dr. Samyyia Abrar supervised the study, provided research guidance, and critically reviewed the research work. Muhammad Umar contributed to data organization, manuscript preparation, writing, editing, and overall development of the manuscript and served as the corresponding author. Faisal Khan assisted with the writing, organization, and editing of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Generative AI Statement: No generative artificial intelligence tools were used in the preparation, writing, or editing of this manuscript.

Publisher's Note: The authors are responsible for the statements and opinions expressed in this manuscript. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

- Adetunji, A., & Obeng-Gyasi, E. (2024). Occupational determinants of health. *Authorea (Authorea)*. <https://doi.org/10.22541/au.170965221.16804913/v1>
- Akram, A., Shabana Nawaz, Maryam Akbar, Tanzeela Iftikhar, Uswa Nawaz, & Anas Jahangir. (2025). Frequency and antimicrobial susceptibility pattern of MRSA in clinical samples. *Insights-Journal of Health and Rehabilitation*, 3(5 (Health and Rehabilitation)), 475–483. <https://doi.org/10.71000/mnngqx64>
- Aldea, A. C., Filofteia Camelia Diguță, Oriana Presacan, Cătălina Voaides, Toma, R. C., & Matei, F. (2025). Detecting antibiotic resistance: Classical, molecular, advanced bioengineering, and AI-enhanced approaches. *Frontiers in Microbiology*, 16, 1673343–1673343. <https://doi.org/10.3389/fmicb.2025.1673343>
- Aqsa Aslam, Wajiha Mahjabeen, Muhammad Zia ul Rehman, Sana Qanber Abbasi, Nazish Babar, & Huzaiifa Saleem. (2022). Antimicrobial susceptibility pattern of methicillin-resistant staphylococcus aureus in a tertiary care hospital. *Journal of University Medical & Dental College*, 13(4), 468–472. <https://doi.org/10.37723/jumdc.v13i4.761>
- Asghar, M. U., Zaidi, A. H., Tariq, M., & Ain, N. U. (2025). Seasonal and hospital settings variations in antimicrobial resistance among clinical isolates from cardiac patients: Insights from a 7-Year study. *BMC Infectious Diseases*, 25(1). <https://doi.org/10.1186/s12879-025-11171-3>
- Babayev, H., & Kurtoğlu, M. (2025). Management of Wound Site Infections. *Abant Medical Journal*, 14(2), 112–129. <https://doi.org/10.47493/abantmedj.1699572>
- Bilal, H., Khan, M. N., Rehman, T., Hameed, M. F., & Yang, X. (2021). Antibiotic resistance in Pakistan: A systematic review of past decade. *BMC Infectious Diseases*, 21(1). <https://doi.org/10.1186/s12879-021-05906-1>
- C, S. (2025). MRSA: Molecular mechanisms of resistance and future directions in antimicrobial therapy. *International Journal of Zoology and Applied Biosciences*, 10(6S), 49–52. <https://doi.org/10.55126/ijzab.2025.v10.i06.sp012>
- Duraisamy, L. N., Somasundram, N. D., & Rangasamy, V. (2020). Community acquired Methicillin Resistant Staphylococcus aureus (CA-MRSA) among skin and soft tissue infections. *International Journal of Current Microbiology and Applied Sciences*, 9(2), 652–657. <https://doi.org/10.20546/ijemas.2020.902.080>
- Elmanama, A. A., Al-Aydi, I. M., & Al-Reefi, M. R. (2020). Biofilm formation and methicillin resistance of staphylococcus aureus isolated from clinical samples. *The International Arabic Journal of Antimicrobial Agents*, 10(1). <https://doi.org/10.3823/841>
- Epidemiological characteristics of 6930 emergency trauma patients in Guangming District, Shenzhen. (2024). *MEDS Clinical Medicine*, 5(4). <https://doi.org/10.23977/medsc.2024.050407>
- Farmanullah, Abbas, W., Parveen, F., Zaman, H., Shah, J., & Rafiullah. (2025). Analysis of hospital-acquired MRSA infections in pus samples: A comprehensive discussion. *Insights-Journal of Health and Rehabilitation*, 3(3 (Health & Allied)), 214–221. <https://doi.org/10.71000/qcamfw64>
- Habibović, S., Jovanović, A., & Ribis, S. (2024). Staphylococcus aureus, the most prevalent isolate among surgically treated patients. *Book of Abstracts - International Congress Public Health – Achievements and Challenges - Zbornik Radova*, 165–165. <https://doi.org/10.5937/batutphco24118h>
- Hussain, M. S., Naqvi, A., & Sharaz, M. (2019). Methicillin resistant staphylococcus aureus (MRSA); *The Professional Medical Journal*, 26(01). <https://doi.org/10.29309/tpmj/2019.26.01.2510>
- Iqbal, S., Bhatti, S. M., Amir, M., Zaman, Q. U., & Raza, A. (2022). Scenario of antibiotic resistance in Pakistan: A systematic review. *Pakistan Journal of Medical and Health Sciences*, 16(5), 643–649. <https://doi.org/10.53350/pjmhs22165643>
- Islam, Md. S. (2025). Phenotypic and molecular strategies for identifying extended-spectrum β -Lactamases: A comprehensive narrative review. *Journal of Current and Advance Medical Research*, 11(2), 115–122. <https://doi.org/10.3329/jcamr.v11i2.86332>
- KG Kaapu, NT Maguga-Phasha, MC Nkambule, & MR Lekalakala-Mokaba. (2023). Gram-positive pathogens in skin and soft tissue infections: Is resistance a challenge in clinical practice? *Journal of Medical Laboratory Science & Technology of South Africa*, 5(2), 88–94. <https://doi.org/10.36303/jmlsta.154>
- Khan, A., Shaikh, A. A., Shah, M. A., & Akram, M. (2025). A cross-sectional study on antibiotic susceptibility profiling of staphylococcus aureus from wound swabs. *Insights-Journal of Health and Rehabilitation*, 3(5 (Health and Allied)), 52–62. <https://doi.org/10.71000/t6hmn464>

- Linz, M. S., Mattappallil, A., Finkel, D., & Parker, D. (2023). Clinical impact of staphylococcus aureus skin and soft tissue infections. *Antibiotics*, 12(3), 557. <https://doi.org/10.3390/antibiotics12030557>
- Okeke, I. N., & Ihekweazu, C. (2021). The importance of molecular diagnostics for infectious diseases in low-resource settings. *Nature Reviews Microbiology*, 19(9), 547–548. <https://doi.org/10.1038/s41579-021-00598-5>
- Osama, M., Asghar, R., Waqas, M., & Ali, N. (2025). Antimicrobial resistance in Pakistan: A silent pandemic at the door. *Journal of Saidu Medical College*, 15(4), 493–494. <https://doi.org/10.52206/jsmc.2025.15.4.1275>
- Perveen, I. (2013). Prevalence and antimicrobial susceptibility pattern of methicillin-resistant staphylococcus aureus and coagulase-negative staphylococci in Rawalpindi, Pakistan. *British Journal of Medicine and Medical Research*, 3(1), 198–209. <https://doi.org/10.9734/bjmmr/2013/2109>
- REPATI GOWRI, S A RAHIL PASHA, PARIMALA S, & ARVIND NATARAJAN. (2024). Analysis of antimicrobial susceptibility pattern of methicillin-resistant staphylococcus aureus in a tertiary care hospital. *Asian Journal of Pharmaceutical and Clinical Research*, 60–63. <https://doi.org/10.22159/ajpcr.2024v17i12.52763>
- Sadat, S. S., & Ahani Azari, A. (2020). Frequency of multidrug-resistant, extensively drug-resistant, and pandrug-resistant phenotypes among clinical isolates of staphylococcus aureus. *Infection Epidemiology and Microbiology*, 6(4), 269–275. <https://doi.org/10.29252/iem.6.4.269>
- Sophian, A. (2025). Building molecular testing capacity for salmonella in foodborne disease surveillance. *Zenodo (CERN European Organization for Nuclear Research)*. <https://doi.org/10.5281/zenodo.17128499>
- Turner, N. A., Sharma-Kuinkel, B. K., Maskarinec, S. A., Eichenberger, E. M., Shah, P. P., Carugati, M., Holland, T. L., & Fowler, V. G. (2019). Methicillin-resistant staphylococcus aureus: An overview of basic and clinical research. *Nature Reviews. Microbiology*, 17(4), 203–218. <https://doi.org/10.1038/s41579-018-0147-4>
- Virginie Papadopoulou, Sidders, A. E., Lu, K.-Y., Velez, A. Z., Durham, P. G., Bui, D. T., Angeles-Solano, M., Dayton, P. A., & Rowe, S. E. (2023). Overcoming biological barriers to improve treatment of a staphylococcus aureus wound infection. 30(5), 513–526.e5. <https://doi.org/10.1016/j.chembiol.2023.04.009>
- Yahaya, K. I. (2023). Isolation and molecular identification of methicillin resistant (MRSA) from different type of wound (cuts, burn and chemical. *IP International Journal of Medical Microbiology and Tropical Diseases*, 9(1), 49–52. <https://doi.org/10.18231/j.ijmmtd.2023.009>