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S.NO	Name	Title	Page.No
1.	**Satish Kumar**	**PERFORMANCE ANALYSIS OF HYBRID AI-DRIVEN MPPT CONTROL FOR SOLAR EV EFFICIENCY AND RANGE ENHANCEMENT**	1-15
2.	**Aarav Verma**	**CULTURAL IDENTITY AND THE PRESERVATION OF INDIGENOUS HERITAGE IN THE DIGITAL ERA**	16-28
3.	**RAVEENDRAN PP**	**ARTIFICIAL INTELLIGENCE-DRIVEN PERSONALIZED FINANCIAL MARKETING AND ITS IMPACT ON FINANCIAL INCLUSION AND CUSTOMER ENGAGEMENT**	29-50
4.	**Imtiaz Khan**	**ANALYZING EDUCATIONAL AND ACADEMIC CHALLENGES FACED BY STUDENTS IN MODERN LEARNING ENVIRONMENTS**	51-62
5.	**Darshan Ganesh Naik**	**FEATURE ENGINEERING AND MACHINE LEARNING FOR AUTOMATED CREDIT SCORING: A PREDICTIVE APPROACH TO LOAN DEFAULT RISK**	63-78
6.	**Prachi Pal**	**A Prospective Comparative Study on Cemented vs. Uncemented Hemiarthroplasty for Displaced Femoral Neck Fractures**	79-91
7.	**Aadhavan Rao**	**COMPARATIVE PERSPECTIVES ON INDIAN AND WESTERN LITERATURE**	92-99
8.	**Vivek Pal**	**Improving Surgical Results for Distal Radius Fractures: Internal Fixation with Volar Locking Compression Plate and Open Reduction**	100-112
9.	**Devendra Verma**	**ASSESSMENT OF FUNCTIONAL OUTCOMES FOLLOWING OPEN REDUCTION AND INTERNAL FIXATION OF DISTAL FEMUR FRACTURES USING LOCKING COMPRESSION PLATES**	113-125
10.	**Avinash Verma**	**A PROSPECTIVE STUDY ON THE FUNCTIONAL OUTCOMES OF ARTHROSCOPIC SUTURE PULL-OUT FIXATION FOR DISPLACED TIBIAL SPINE AVULSION FRACTURES**	126-136

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PERFORMANCE ANALYSIS OF HYBRID AI-DRIVEN MPPT CONTROL FOR SOLAR EV EFFICIENCY AND RANGE ENHANCEMENT

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ABSTRACT

The integration of solar photovoltaics (PVs) with electric vehicles (EVs) becoming more common, there is need to come up with effective control systems to ensure proper utilization of renewable energy under varying weather conditions. In this study, an artificial intelligence (AI) based hybrid maximum power point tracking (MPPT) controller was suggested for improvement of solar energy harvesting and Solar EV performance. The suggested hybrid MPPT controller incorporated both AI-based decision-making and traditional MPPT approaches and was compared to P&O and INC algorithms using a Solar EV simulation system. Performance was evaluated in conditions of high, reduced, varying and rapidly varying irradiance and temperature conditions using MPPT efficiency, tracking time, tracking error, power variations, solar energy harvesting, battery SOC and driving range. The Hybrid AI-MPPT controller had an average MPPT efficiency of 98.7%, against 95.2% in case of INC and 91.4% in case of P&O. This controller reduced the average time required for tracking to 62 ms. The tracking error and power fluctuation were minimum in case of Hybrid AI-MPPT at 1.9% and 1.3%, respectively. The proposed controller was capable of extracting 814 Wh from the solar energy source and attained a final battery SOC of 82.3%, leading to an estimated driving range of 131.5 km. As compared to P&O, the proposed method increased the estimated driving range by 5.79%.

Keywords: *Hybrid Artificial Intelligence, Maximum Power Point Tracking, Solar Electric Vehicle, Photovoltaic System, P&O, Incremental Conductance, Battery Charging, Energy Utilization, Driving Range, Renewable Energy*

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1. INTRODUCTION

The increased usage of EV requires an efficient source of sustainable and reliable energy. The use of solar PV energy offers the best alternative towards renewable energy integration within EV charging stations. However, PV energy is continuously varying depending on irradiance and temperature of the sun, hence making effective solar energy extraction quite difficult. Intelligent control techniques may assist in energy extraction within dynamic conditions.

MPPT is very important within PV based EV applications since it helps in the operation of the PV system close to the maximum power point. Traditional methods like perturb and observe (P&O) and incremental conductance (INC) are quite popular but their effectiveness may reduce in case of rapidly changing irradiance and temperatures. They may also result in slow tracking and oscillations at the maximum power point.

AI-based MPPT along with Solar EVs may help optimize PV energy extraction and battery charging, making better use of the generated energy. Optimizing the performance of MPPT may result in increased energy being delivered to the batteries, thus making a positive contribution to driving range. It is necessary to examine the performance of the MPPT at PV and vehicle levels in order to assess its practical efficiency in Solar EVs.

This research intends to design a Hybrid AI-based MPPT controller for efficient PV energy extraction from Solar EVs in different environmental conditions and comparing its efficiency with traditional MPPT approaches.

This research presents the Hybrid AI-based MPPT controller along with an analysis of the performance of such a controller compared to the performance of the conventional methods such as P&O and INC algorithms. The proposed method involves integration of the AI-based decision-making process along with the conventional MPPT technique. In this context, the evaluation of MPPT efficiency, tracking time, tracking error, power variation, energy utilization, charging efficiency of batteries and driving range is carried out.

ISBN Number: 978-93-88136-57-0

2. LITERATURE REVIEW

Khan et al. (2024) investigated both traditional MPPT algorithms and AI-based MPPT techniques to optimize solar energy production. According to their research, the use of AI systems provided higher accuracy, flexibility, and efficiency in varying PV conditions. In addition, the research revealed that conventional systems might be less effective in dynamically changing operation conditions.

Govindasamy et al. (2023) examined the application of IoT- and AI-enabled MPPT algorithms to hybrid systems with solar panels and fuel cells. As was seen from their research, intelligent control enhanced the use of renewable energy and stressed the necessity of implementing adaptive MPPT depending on operating conditions. This showed that intelligent control is needed to ensure efficient energy extraction.

Salman et al. (2025) explored the use of machine learning and metaheuristics algorithms in MPPT for solar PV energy systems. This research revealed the effectiveness of intelligent optimization techniques in maximizing solar energy generation and highlighted the need for efficiency and tracking accuracy. Moreover, this research highlighted the need for efficient computation techniques to enhance MPPT performance.

Pal and Bhattacharya (2025) studied AI assisted Control of DC-DC converter in a solar MPPT based off grid charging station for EVs. Results showed the relevance of AI control for optimizing solar charging, yet with potential to examine its impact on energy efficiency and driving distance. This study hence laid a foundation for future study on intelligent MPPT analysis for Solar EVs

Prajapati et al. (2025) investigated the incorporation of AI in solar energy-based charging stations for EVs and analyzed its implications in terms of enhancing energy efficiency and charging efficiency. This work identified the need for adaptive intelligent control, which serves as a foundation for the current research that deals with the implications of Hybrid AI-MPPT in PV harvesting, battery efficiency, and Solar EV driving range.

ISBN Number: 978-93-88136-57-0

3. RESEARCH METHODOLOGY

The research "Performance Analysis of Hybrid AI-driven MPPT Control for Solar EV Efficiency and Range Enhancement", the methodology involves designing, simulating and assessing a hybrid AI-based MPPT controller for solar EVs. The methodology combines PV system modeling, AI-based MPPT control design, EV energy management, simulation-based assessment of performance, and comparison with existing MPPT methods.

3.1 Overall Research Framework

The research project is based on the simulation approach consisting of PV modeling, environmental conditions creation, Hybrid AI-MPPT design, Solar EV implementation, performance evaluation, and comparison. The AI-based MPPT controller controls the DC-to-DC converter and maximizes power output to the EV battery using PV voltage, current, irradiance, and temperature. The simulation model can be defined by Solar Irradiance & Temperature → PV Array → Hybrid AI-MPPT → DC-to-DC Converter → EV Battery → Motor/Drive → Vehicle Performance.

3.2 Modelling of the Photovoltaic Energy System

PV array modeling is done for the representation of solar energy source of the Solar EV. PV system can be described based on its I–V and P–V curves, which depend upon solar intensity and cell temperature.

The expression for power obtained from the PV array is:

$$P_{PV} = V_{PV} I_{PV}$$

where P_{PV} is the PV output power, V_{PV} is PV voltage, and I_{PV} is PV current.

PV system is simulated at three different irradiances along with three different temperatures. The PV voltage, current, and power are used as input in the MPPT algorithm to evaluate the performance of the algorithm under both static and dynamic solar conditions.

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3.3 Development of the Hybrid AI-Driven MPPT Controller

The suggested hybrid AI-based MPPT controller uses AI-based prediction along with traditional MPPT control to provide more rapid and accurate tracking of maximum power. It takes PV voltage, current, power, their variations, solar radiation intensity, and temperature as input parameters to decide about the suitable control input to the converter, whereas the traditional MPPT control makes the system more stable and reliable.

The control error can be written as:

$$e(k) = P_{MPP}(k) - P_{PV}(k)$$

where P_{MPP} represents the estimated maximum available PV power and P_{PV} represents the instantaneous PV power.

The AI controller is continually adjusting the control signal based on the PV operational condition and sending the signal to the DC-DC converter to operate close to the maximum power point. Hybrid design leads to increased response rate, decreased power oscillations, and efficient energy generation during dynamic conditions.

3.4 Integration with the Solar EV Energy System

The designed MPPT controller is combined with the Solar EV, which includes PV module, DC-DC converter, battery, electric motor, and EV load. The DC-DC converter couples the PV module to the battery, while MPPT controller controls the duty cycle for maintaining the optimum operating point of the PV module. The battery model takes into account the SOC, voltage, charging current, available energy, and charging efficiency for studying the use of solar energy.

The electrical energy that is available to the propulsion system can be described as:

$$E_{EV} = \int P_{EV}(t)dt$$

where E_{EV} represents the energy supplied to the EV propulsion system.

ISBN Number: 978-93-88136-57-0

It allows the researcher to be able to find out if there is better utilization of battery due to improved energy extraction using the MPPT approach.

3.5 Simulation Scenarios and Experimental Conditions

A simulation-based method is employed for testing the efficacy of the developed controller under irradiation being constant/high, low irradiation, varying irradiation, temperature variation, transient irradiation change, and environmental condition scenarios. These test the baseline performance, low solar irradiation performance, dynamic performance, temperature tolerance, transient performance, and overall realistic performance. The Hybrid AI-MPPT controller is tested against the P&O and INC using the identical solar array, power converter, battery, and car model along with environmental conditions.

3.6 Performance Evaluation Metrics

The performance of the suggested controller is analyzed using numerical parameters associated with the MPPT technique as well as the Solar EV.

The primary efficiency of MPPT is defined as:

$$\eta_{MPPT} = \frac{P_{available}}{P_{tracked}} \times 100$$

where $P_{tracked}$ is the power extracted by the controller $P_{available}$ and is the maximum available PV power.

The performance of the suggested controller is measured using the efficiency of MPPT, tracking time, tracking error, power generation from PV, battery charging efficiency, energy usage, and the driving range of the Solar EV.

3.7 Comparative Analysis and Validation

The suggested Hybrid AI-MPPT control strategy is critically analyzed against P&O and INC approaches in terms of their performance at controller level and Solar EV level via MPPT

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efficiency, tracking time, power variation, tracking error, battery charging, energy harvesting, and driving distance. Tables and graphs of PV power, MPPT performance, battery state of charge, and vehicle energy consumption are utilized for performance comparison and mean values and percentages of improvement are considered in case of repeatable simulation results.

4. RESULTS AND DISCUSSION

This section describes the simulation results for the developed Hybrid AI-MPPT control algorithm and compares the performance of this algorithm with conventional P&O and INC methods. This analysis is based on PV power extraction, MPPT efficiency, response dynamics, energy efficiency, charging of batteries, and Solar EV driving range at various operating conditions. The simulation results have been presented in comparative tables and graphs that help to analyze the efficacy of the developed control system for harvesting solar energy.

The PV power harvested by the P&O, INC, and Hybrid AI-MPPT algorithms at six different irradiation and temperature conditions is described in Table 1 below. Also, the available PV power for each operating condition is shown.

Table 1: Comparative PV Power Extraction Performance

Operating Condition	**Available PV Power (W)**	**P&O (W)**	**INC (W)**	**Hybrid AI-MPPT (W)**
High irradiance	1020	975	992	1012
Reduced irradiance	610	570	589	603
Variable irradiance	850	778	812	839
Temperature variation	790	724	751	779
Rapid irradiance change	920	817	861	906
Combined variation	840	735	784	825

ISBN Number: 978-93-88136-57-0

From Table 1 above, Hybrid AI-MPPT produces more PV power than both P&O and INC algorithms. It produces 1012 W when irradiance is high and 906 W at the stage of fast change of irradiance, while P&O algorithm produces 975 W and 817 W respectively. From the above figures, it is clear that the proposed controller is working near the maximum power point most of the time.

Figure 1 below gives a graphical comparison of the extracted PV power from P&O, INC, and Hybrid AI-MPPT controllers for the six operating conditions.

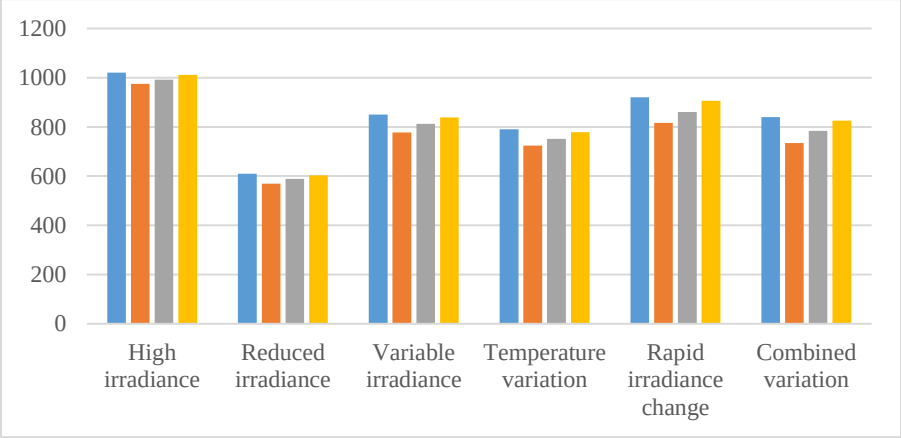


Figure 1: Graphical Representation of Comparative PV Power Extraction Performance

From Figure 1 below, Hybrid AI-MPPT achieves the highest extraction of power among all cases. Its extraction power is close to the actual PV power, but P&O has the highest deviation from it, and INC performs moderately in comparison. The increased adaptability of the proposed controller is thus proven by the results.

The efficiency of P&O, INC, and Hybrid AI-MPPT in MPPT for different values of irradiation and temperature is provided in Table 2 below.

Table 2: Comparative MPPT Efficiency

Operating Condition	**P&O (%)**	**INC (%)**	**Hybrid AI-MPPT (%)**
High irradiance	95.6	97.3	99.2

ISBN Number: 978-93-88136-57-0

Reduced irradiance	93.4	96.6	98.9
Variable irradiance	91.5	95.5	98.7
Temperature variation	91.6	95.1	98.6
Rapid irradiance change	88.8	93.6	98.5
Combined variation	87.5	93.3	98.2
Average	**91.4**	**95.2**	**98.7**

As per Table 2, Hybrid AI-MPPT has the highest efficiency under all circumstances with the average of 98.7% efficiency. INC has 95.2%, whereas P&O has the efficiency of 91.4%. The maximum difference is observed when there is the fast irradiance change and the efficiency of Hybrid AI-MPPT comes to be 98.5%.

Graphical representation of MPPT efficiency under three controllers for different operating conditions is shown in Figure 2.

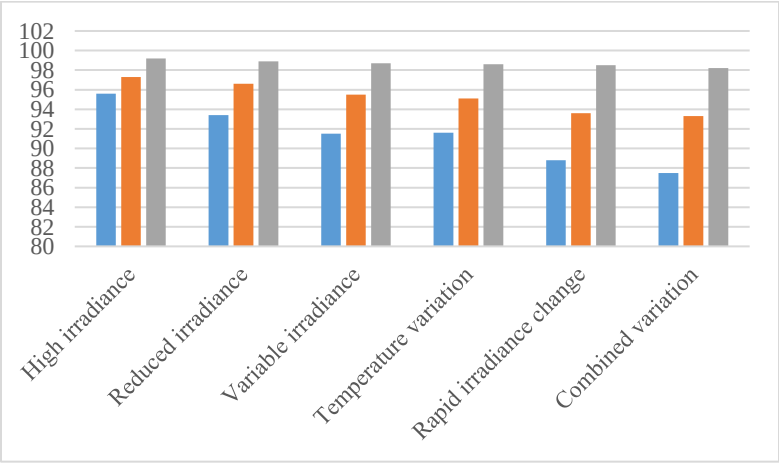


Figure 2: Graphical Representation of Comparative MPPT Efficiency

Hybrid AI-MPPT, as depicted in Figure 2, is observed to have a minimum efficiency rate of above 98% in all cases. The largest decrease in efficiency for P&O is recorded during varying situations,

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while INC exhibits better efficiency but does not match the efficiency level of the Hybrid AI-MPPT.

Table 3 provides a comparison of the dynamic response of the three MPPT controllers based on tracking time, power fluctuation, and tracking error.

Table 3: MPPT Dynamic Response Performance

Performance Parameter	**P&O**	**INC**	**Hybrid AI-MPPT**
Average tracking time (ms)	145	108	62
Maximum tracking time (ms)	190	145	84
Average power fluctuation (%)	4.8	2.9	1.3
Average tracking error (%)	8.6	4.8	1.9

Table 3 shows that Hybrid AI-MPPT gives the highest response speed and stability. It has the shortest average tracking time of 62 ms, while INC and P&O have average tracking times of 108 and 145 ms, respectively. It also shows the least power fluctuation and tracking error of 1.3% and 1.9%, respectively.

Figure 3 gives the graphical representation of the tracking time, power fluctuation, and tracking error of P&O, INC, and Hybrid AI-MPPT.

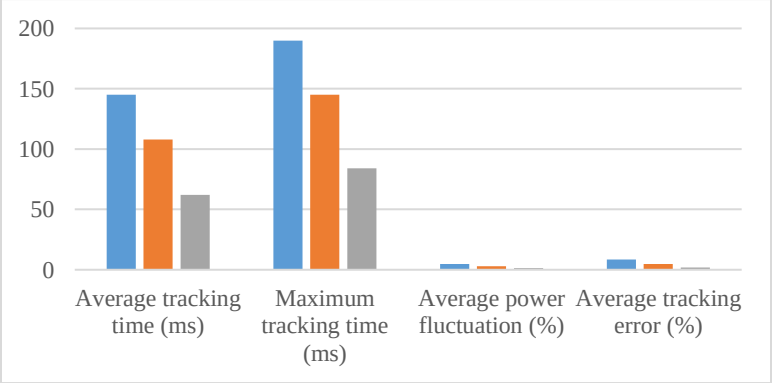


Figure 3: Graphical Representation of MPPT Dynamic Response Performance

ISBN Number: 978-93-88136-57-0

It can be seen from Figure 3 that Hybrid AI-MPPT has the lowest dynamic performance indicators for all three categories. The lower tracking time indicates better adaptability, while the lower fluctuation and error mean better stability at the maximum power point.

Table 4 presents a comparison of solar energy harvesting, battery charging energy, efficiency of charging, energy loss, and final battery SOC for all three MPPTs.

Table 4: Battery and Energy Utilization Performance

Parameter	**P&O**	**INC**	**Hybrid AI-MPPT**
Solar energy extracted (Wh)	742	781	814
Battery charging energy (Wh)	690	729	762
Charging efficiency (%)	93.0	93.3	93.6
Energy loss (Wh)	52	52	52
Final battery SOC (%)	78.4	80.1	82.3

Table 4 demonstrates that Hybrid AI-MPPT achieves the highest amount of solar energy extraction in 814 Wh and the highest charging energy to the battery in 762 Wh. The maximum value of its battery state of charge is 82.3%, while 80.1% for INC and 78.4% for P&O.

Table 5 provides comparison of usable energy of the battery, average energy consumption per km of a vehicle and the driving range of the vehicle based on three MPPT approaches.

Table 5: Solar EV Driving Range Comparison

Parameter	**P&O**	**INC**	**Hybrid AI-MPPT**
Usable battery energy (kWh)	18.4	18.8	19.2
Average vehicle consumption (Wh/km)	148	147	146
Estimated driving range (km)	124.3	128.0	131.5

ISBN Number: 978-93-88136-57-0

Range improvement over P&O	—	2.98%	5.79%

The table 5 above indicates that Hybrid AI-MPPT has the highest amount of usable battery energy and driving range. This system is estimated to have the range of 131.5 km, while INC and P&O have ranges of 128.0 km and 124.3 km, respectively. Therefore, the approach under study improves the range by 5.79% over P&O.

The table 6 below compares P&O, INC, and Hybrid AI-MPPT based on Solar EV performance criteria.

Table 6: Overall Performance Comparison of MPPT Controllers

Performance Indicator	**P&O**	**INC**	**Hybrid AI-MPPT**
Average MPPT efficiency (%)	91.4	95.2	98.7
Average tracking time (ms)	145	108	62
Average tracking error (%)	8.6	4.8	1.9
Power fluctuation (%)	4.8	2.9	1.3
Solar energy extracted (Wh)	742	781	814
Final battery SOC (%)	78.4	80.1	82.3
Estimated range (km)	124.3	128.0	131.5

According to Table 6, the Hybrid AI-MPPT model exhibits superior performance. The model is more efficient in terms of MPPT efficiency and PV energy collection, and its tracking time, error, and power variation are also minimal. Moreover, it generates the maximum battery state of charge and predicted driving range. In general, the outcomes reveal that the designed control system has outperformed the P&O and INC models.

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4.1 Discussion of Findings

The findings confirm the superiority of the designed Hybrid AI-MPPT controller over traditional P&O and INC approaches in various operating conditions of the PV system. The higher extraction of the PV power under varying irradiance, temperature change, and sudden irradiance change is evident from Table 1 and Figure 1. Table 2 and Figure 2 revealed an MPPT efficiency of 98.7% for the Hybrid AI-MPPT, 95.2% for INC, and 91.4% for P&O; the Hybrid AI-MPPT maintained its efficiency of 98.5% during sudden irradiance change.

The dynamic performance results given in Table 3 and Figure 3 revealed that Hybrid AI-MPPT had better and faster tracking performances with a minimum average tracking time of 62 ms, as opposed to 108 ms for INC and 145 ms for P&O. The Hybrid AI-MPPT produced the smallest power variation (1.3%) and tracking errors (1.9%). According to Table 4, the proposed controller harvested 814 Wh of solar energy and 762 Wh were delivered to the battery, and a final battery SOC of 82.3% was obtained, as compared with 80.1% and 78.4% of INC and P&O, respectively.

As can be seen in Table 5, the maximum estimated driving range was 131.5 km for the Hybrid AI-MPPT, which was better than 128.0 km for the INC method and 124.3 km for P&O method, thus resulting in a 5.79% improvement over P&O method. From Table 6, it can be observed that the performance of the proposed controller was better in terms of efficiency, energy extraction, and with less tracking time, error, and power fluctuation.

5. CONCLUSION

It was found that the suggested Hybrid AI driven MPPT controller outperformed the traditional P&O and INC methods of Solar EVs. The hybrid approach offered an MPPT efficiency of 98.7%, fast tracking (with an average response time of 62 ms), minimal error and fluctuations of the solar energy tracking, and higher energy collection of 814 Wh. All these factors led to a greater SOC (state of charge) of the battery which equaled to 82.3% and an extended driving range which was 131.5 km and was a 5.79% improvement compared to P&O. In general, the results indicated that the implementation of the AI-based decision making into the traditional MPPT increased the solar

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energy collection and battery energy usage, and hence driving capabilities of Solar EVs under different environmental conditions.

REFERENCES

1. *Areola, R. I., Adebiyi, A. A., & Moloi, K. (2025). Artificial intelligence for optimizing solar power systems with integrated storage: A critical review of techniques, challenges, and emerging trends. Electricity, 6(4), 60.*
2. *Arsad, A. Z., Azhar, A. D., Arsad, S. R., Zuhdi, A. W. M., Chau, C. F., & Ghazali, A. (2025). Towards artificial intelligence for solar charge controller: an analytical study of recent status, optimization and module development. Energy Systems, 1-54.*
3. *Azad, A. S., Islam, N., Nabi, M. N., De Silva, S., & Sokkalingam, R. (2025). Artificial Intelligence Applications in Hybrid Renewable Energy Systems: A Comprehensive Review of Techniques, Applications, and Challenges. Applications, and Challenges.*
4. *Ghazi, G. A., Al-Ammar, E. A., & Hasanien, H. M. (2025). Performance enhancement of grid-connected PV system using artificial intelligence techniques. Journal of Electrical Engineering & Technology, 20(8), 4959-4987.*
5. *Govindasamy, M., Cyril Mathew, O., Kumar Boopathi, M., & Chandran, G. (2023). Iot and AI-based MPPT techniques for hybrid solar and fuel cell. Electric Power Components and Systems, 1-21.*
6. *Khalid, S. (2025). Advanced electric propulsion systems for hybrid electric vehicles: Design, control, and performance optimization. In Hybrid Electric Vehicles and Distributed Renewable Energy Conversion: Control and Vibration Analysis (pp. 1-54). IGI Global Scientific Publishing.*
7. *Khan, M., Raza, M. A., Faheem, M., Sarang, S. A., Panhwar, M., & Jumani, T. A. (2024). Conventional and artificial intelligence based maximum power point tracking techniques for efficient solar power generation. Engineering Reports, 6(12), e12963.*
8. *Mamodiya, U., Kishor, I., Garine, R., Ganguly, P., & Naik, N. (2025). Artificial intelligence based hybrid solar energy systems with smart materials and adaptive photovoltaics for sustainable power generation. Scientific Reports, 15(1), 17370.*

ISBN Number: 978-93-88136-57-0

9. *Mbonu, C. I., & Tamba II, J. S. (2025). AI-Driven MPPT Optimization for Perovskite-Based Flexible Solar PV Panels in Partial Shading Conditions. IDOSR JOURNAL OF APPLIED SCIENCES Учредители: International Digital Organization for Scientific Research, 10(1), 36-43.*

10. *Pal, S., & Bhattacharya, A. (2025, October). Artificial intelligence assisted optimization control of dab converter in mppt-based off-grid solar ev charging station. In 2025 IEEE 2nd International Conference on Green Industrial Electronics and Sustainable Technologies (GIEST) (pp. 1-6). IEEE.*

11. *Prajapati, A., Paraye, P., Ahirwar, B. K., & Tam, C. F. (2025). Artificial intelligence integration in solar-powered EV charging systems: challenges, opportunities, and future perspectives: A. Prajapati et al. Journal of Thermal Analysis and Calorimetry, 150(16), 12103-12134.*

12. *Salman, D., Elmi, Y. K., Isak, A. M., & Sheikh-Muse, A. (2025). Evaluation of MPPT Algorithms for Solar PV Systems with Machine Learning and Metaheuristic Techniques. Mathematical Modelling of Engineering Problems, 12(1), 115.*

13. *Tamilamuthan, R., Sridevi, T., Navaprakash, N., Geetha, B. T., & Lakshmanan, M. (2025, December). Embedded C-based Adaptive MPPT Controller with Boost Converter for High-Efficiency Solar-Powered Electric Vehicle Charging Applications. In 2025 6th International Conference on IoT Based Control Networks and Intelligent Systems (ICICNIS) (pp. 181-187). IEEE.*

14. *Thamizharasan, R., Ramathilagam, K., Mythili, R., Sukitha, D., & Sivakarthikeyan, G. (2025, December). AI-Driven Optimization of EV Battery Charging. In 2025 12th National Power Electronics Conference (NPEC) (pp. 1-6). IEEE.*

15. *Tripathi, A. P., & Kumar, A. (2025, December). Advancements in AI-Based MPPT Algorithms for Optimizing Solar Power Systems in Electric Vehicle Charging Stations. In 2025 IEEE 1st International Conference on Recent Trends in Computing and Smart Mobility (RCSM) (pp. 1-5). IEEE.*

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CULTURAL IDENTITY AND THE PRESERVATION OF INDIGENOUS HERITAGE IN THE DIGITAL ERA

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Research Scholar

ABSTRACT

Cultural identity is closely related to the traditions, languages, knowledge systems, artistic expressions, beliefs, customs and collective memories that through which communities understand and represent themselves. Indigenous communities have different types of tangible and intangible heritage which are now increasingly impacted by globalization, modernization, migration, linguistic shift and change in cultural transmission. Meanwhile, the swift advancement of digital technologies has opened new avenues to document, preserve, transmit and promote indigenous heritage. Cultural knowledge can be made available to younger generations and other audiences through digital archives, social media, online repositories, audiovisual records, and mobile applications and digital language resources. But digital preservation also raises issues about cultural ownership, privacy, false attribution, commercialization, appropriation of cultural heritage and the loss of community control of TK. This paper looks at the connection between cultural identity and the preservation of indigenous heritage in the digital age using a qualitative secondary-source review. It examines the opportunities that digital technologies offer and considers some of the key challenges that arise with digital cultural preservation. Special focus on indigenous languages, oral traditions, indigenous knowledge, and artistic traditions and community engagement. The paper also takes into account the Indian context, with current government efforts in documenting and promoting the cultural heritage of the tribes. The study proposes that technology should be used as an enabling tool and not take the place of a community-based cultural practice. To achieve sustainable digital preservation, it is important to see the meaningful engagement of indigenous peoples, ethical data governance, cultural sensitivity, and digital inclusion and recognition of community ownership.

Keywords: *Cultural Identity, Indigenous Heritage, Digital Preservation, Indigenous Languages, Digital Technology*

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1. INTRODUCTION

Culture gives community and people a sense of belonging, continuity and identity. It is manifested in language, traditions and rituals, social practices, artistic expression, oral history, traditional knowledge and relationships to specific places and natural environments. Cultural heritage for Indigenous communities is more than a repository of historical things or traditions. It is a living entity by which knowledge, values and collective memory can be passed down from one generation to the next (Ajani et al., 2024).

According to the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, intangible heritage is practices, representations, expressions, knowledge and skills that communities consider to be part of their cultural heritage. Such heritage includes oral traditions and languages, performing arts, social practices, rituals, knowledge concerning nature and traditional craftsmanship. Importantly, UNESCO highlights the roles communities play in the production, maintenance, protection and recreation of such heritage.

The importance of the preservation of indigenous heritage has grown in critical significance due to the many pressures indigenous cultures are experiencing in the context of globalization and modernization, migration, linguistic marginalization and socioeconomic change. Loss of traditional languages, disruption of oral traditions and a disaffiliation of youth to customary practices can have an impact on cultural continuity.

In this context, there are opportunities and challenges in the digital era (Dutta, 2019). The digital technologies have changed how cultural information can be recorded, stored, accessed and transmitted. Oral traditions and performances can be recorded on tape and video, and photographs, manuscripts, artworks and historical records can be captured and stored on digital archive. Social media can be used to allow indigenous communities to share their culture and tell their stories to the broader community. Digital language tools can also serve as an aid to continued use and learning of indigenous languages (Conti, 2025).

According to UNESCO, digital technologies have the potential to help document, transmit and revitalise ICH. It is also important to highlight that at the same time, it is digital circulation that

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brings up the issue of cultural property rights, and that communities must continue to be at the heart of the processes of documentation and circulation.

Then the argument for the indigenous culture/technology can not only be seen as a dichotomy between tradition and modernity (Qureshi et al., 2025). Rather, digital technologies can serve as tools that can be used to help communities continue to be "cultural," as long as they have legitimate control over the documentation and dissemination of their knowledge and cultural expressions.

The study aims at accomplishing the following objectives:

1. To examine the relationship between cultural identity and indigenous heritage.
2. To explore the role of digital technologies in preserving indigenous cultural heritage.
3. To examine how digital platforms contribute to the transmission of indigenous knowledge and cultural practices to younger generations.
4. To identify the major opportunities associated with the digital preservation of indigenous languages, traditions and knowledge.
5. To analyse challenges related to cultural ownership, representation, accessibility and digital appropriation.
6. To suggest measures for ethical, inclusive and community-centred digital preservation of indigenous heritage.

2. AREA OF RESEARCH

The present research is an interdisciplinary study, both in Cultural Studies, Indigenous Studies and Digital Humanities, which focuses on the retention of indigenous cultural heritage using digital technologies.

The primary focus of the study is on intangible aspects of indigenous heritage such as:

- indigenous and tribal languages;
- oral traditions and folklore;

ISBN Number: 978-93-88136-57-0

- traditional knowledge systems;
- rituals, festivals and social practices;
- traditional music, dance and performing arts;
- crafts, visual arts and material culture;
- ecological and nature-related knowledge; and
- collective memories and cultural narratives.

Digital Preservation is also addressed in this research as the methods of online archiving, digital museums, audiovisual recording, social networking, mobile apps, digital educational tools, and other information and communication technology.

The Indian perspective becomes especially pertinent owing to the fact that there are many examples of diversity within tribal groups and indigenous communities within the territory of India. The government recognizes the importance of documenting, preserving, and promoting languages, art, folklore, and indigenous knowledge among tribal populations. For instance, the Ministry of Tribal Affairs reported about the efforts of Tribal Research Institutes, who documented the tribal languages, folklore, and traditional knowledge.

3. METHODOLOGY

The research in the present study is a qualitative and descriptive research using secondary sources. A primary survey or questionnaire has not been used, and the study does not state the statistical findings of the respondents.

The scholarly literature, institutional publications, UNESCO publications, government documents and credible digital sources that had been relevant to the study of indigenous heritage, cultural identity, digital preservation and indigenous languages were collected. One important focus was international instruments on intangible cultural heritage and current projects on digital heritage.

The material collected was analysed thematically. The key themes that were identified were: digital documentation, indigenous languages, intergenerational transmission, digital

ISBN Number: 978-93-88136-57-0

representation, community participation, digital inclusion, cultural ownership and ethical preservation. The discussion is thus based on available evidence, and not on the artificially produced results as numbers.

The methodology is suitable for the study of a subject with multiple dimensions (cultural, technological, social and ethical), which requires a multidisciplinary approach.

4. RESULTS AND DISCUSSION

This analysis looks at the opportunities and challenges discussed from a thematic perspective, especially the use of technology in enhancing cultural identity and ensuring that indigenous culture remains intact.

4.1 Digital Technology as a Tool for Heritage Preservation

Digital technologies have greatly enhanced the opportunities for safeguarding cultural heritage. Conventional means of documenting have often relied on physical documentation, museums, print media and local collection centers (Shiri et al., 2022). Such means continue to play a major role in this process; however, there exist other options available in the context of digital technologies.

These include audio/video recordings for songs, stories and oral traditions; photography for crafts, fashion and works of art; as well as digital catalogues to organize vast collections of materials. Digital museums and online exhibits will further allow those who are far away geographically from a certain community to know their culture (Singh & Kumar, 2024).

The experience of UNESCO in using digital technologies to document culture demonstrates that digital mapping, online museums, 3D modeling and other platforms are some of the means that are employed in this area.

However, it is important to note that digitizing cultural heritage in no way constitutes its preservation by itself. The recording of a ceremony preserves its audio/visual record but not necessarily the social context, the spiritual aspect and the relationships within the community where it is performed (Taylor et al., 2018).

ISBN Number: 978-93-88136-57-0

4.2 Digital Documentation of Indigenous Knowledge

The indigenous communities have large amounts of knowledge concerning agriculture, medicine, biodiversity, ecology, crafts, foods, and interactions with the environment. A lot of the knowledge has been passed down through generations using oral tradition or practical engagement (Kiftiyah & Fitria, 2025).

Digital documentation can assist in the protection of this knowledge as it might be lost when there is no proper transfer between generations. Interviewing people, taking pictures, collecting oral history, and other educational materials can provide a record for the future.

However, this knowledge cannot be thought of as common information which can be used indiscriminately. There might be some types of knowledge which are sacred, private or restricted by customs. It is necessary to differentiate public and restricted knowledge when documenting (Malik & Farooq, 2025).

In this sense, the recent works of UNESCO concerning Indigenous knowledge and digital technology are similar – they recognize the potential of technology to document languages and traditions, but point out the need for ethical use and ownership.

4.3 Indigenous Languages in the Digital Space

Language is considered one of the strongest markers of culture. Language is rich in unique concepts, history, oral tradition, and relations to the environment (Zulkarnain, 2024). Thus, the death of an indigenous language may result not only in the inability to communicate but also cultural memory and identity loss (Gafurova et al., 2022).

There are numerous opportunities for language revitalization within the digital environment. For example, digital dictionaries, online courses, applications for mobile devices, recordings of dialogues, digital stories, and other digital resources could help to make indigenous languages visible and functional for young people (Manžuch, 2017).

The UNESCO projects dedicated to digital initiatives for indigenous languages state that digital resources may become important instruments for conservation, revitalization, and promotion of

ISBN Number: 978-93-88136-57-0

indigenous and marginalized languages. At the same time, the organization mentions the serious global threat to languages and focuses on community-led digital approaches.

In particular, the process of digital inclusion is especially important due to the fact that young people use digital resources to communicate. In case indigenous languages are not used within the digital environment, their usefulness and actuality for modern society could be lost.

4.4 Social Media and Intergenerational Cultural Transmission

Social media has helped to birth new cultural identities. Traditional songs, dances, stories, art, food traditions, clothing, and local history can be shared by Indigenous youth via digital platforms (Zhou, 2025). The practices can foster a sense of identity and generational engagement with community traditions. Social media can also provide indigenous people with a platform to present themselves without being solely reliant on external institutions and media. This change is significant for cultural representation created by outsiders can be presented in a simple or stereotypical way in relation to indigenous identities. Meanwhile, social platforms are spurring the quick dissemination of culture. The traditional image, song, design or ceremony can be reproduced off context. More visibility, however, does not necessarily lead to more cultural protection. The importance of social media will thus rely on the manner that communities use it and whether they still have management over the content that is being disseminated through social media.

4.5 Digital Representation and Cultural Identity

Digital representation can enhance cultural identity because it can make indigenous heritage visible in the present-day public domain. Digital community websites, archives, and online exhibits can help dispel the notion that indigenous cultures are only of the past. Representation, however, also comes with questions of power (Bihari, 2023). Who is represented by the cultural practices? Who is giving the interpretation? Who is the person in the pictures, video or recording? These questions are at the heart of the responsible digital heritage preservation. A community-centred approach gives culture(s) practitioners, elders, youth and knowledge holders a voice in the representation of their culture(s). According to the Convention of UNESCO 2003, communities, groups and individuals can play a vital role in creating, preserving and transmitting the ICH.

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4.6 Opportunities Created by Digitalisation

There are several salient points to be highlighted from the connection between indigenous heritage and digital technology.

Digital platforms can be more accessible in the first place. Community members who reside outside the area of their cultural heritage can use cultural resources.

Second, digital tools can help in passing information along to the next generation (Alivizatou-Barakou et al., 2017). Cultural knowledge can be accessed in a way that is normal to young people, including in a mobile app, video and online learning.

Third, digital documentation can be used to aid research and education. Ethically accessible digital collections can be used by scholars, teachers and students to gain an understanding of indigenous history and culture.

Fourth, digital platforms have the potential to boost cultural visibility. The communities can share their stories and success with the nation and world.

Fifth, digital projects can help in the language revitalization by providing opportunities to use indigenous languages in digital communication.

Here India is a good example. According to the Ministry of Tribal Affairs, TribeX is an online platform which aims to document, preserve, share and promote tribal communities' rich cultural heritage and traditional knowledge systems. The platform also features tools and information about tribal craftsmanship, art, handicrafts, textiles, musical instruments and other cultural expressions.

4.7 Challenges of Cultural Appropriation and Misrepresentation

However, the digitization of the heritage of indigenous people poses some dangers. Cultural materials posted online can be reproduced, modified, commercialized and distributed without permission from their respective communities.

Cultural appropriation is especially challenging when traditional designs, knowledge, songs, and symbols are commercially used without adequate attribution or benefit-sharing. On the same note,

ISBN Number: 978-93-88136-57-0

culture is posted online in such a way that there is no historical, spiritual or social context about it, which ends up with stereotyping or misunderstanding.

There needs to be a certain set of guidelines in digital preservation that will outline issues of permission, attribution, access and usage. The dangers posed by the digital technology on living heritage have been realized by UNESCO.

4.8 Digital Divide and Unequal Access

The advantages of digital preservation cannot be shared evenly by all. Indigenous people who live in isolated regions, in which internet access, power supply, technology and training may be scarce, for example.

A digital preservation project that disregards this digital divide might unknowingly perpetuate inequality. These communities would be objectified into being documented yet not have the technological means necessary to control and access these digital resources.

As such, it is important that digital preservation includes capacity building and digital literacy. This would entail community members receiving training not only to provide cultural content but to engage in recording, cataloging, editing, archiving and management of digital material.

4.9 Community Ownership and Ethical Digital Preservation

The key issue which has emerged out of the discussion is that indigenous communities cannot be looked upon only as providers of cultural data. They should be regarded as decision-makers.

Ethical digital preservation should take into account issues such as:

- Who owns the digital record?
- Who can access it?
- Which cultural materials can be publicly shared?
- How should sacred or restricted knowledge be protected?
- How should community contributors be acknowledged?

ISBN Number: 978-93-88136-57-0

- Can cultural materials be commercially reused?
- How will the digital archive remain accessible in the long term?

UNESCO's intangible cultural heritage definition puts communities at the heart of the safeguarding process and requires their involvement in the process of management. Recent research also supports this community-based approach. In a review of 79 studies on digital intangible cultural heritage safeguarding in 2026, technology was shown to be most effective when accompanied by a meaningful community involvement, and projects based on technology with little community involvement can lead to "digital fossilization," as the researchers put it."

4.10 Indian Context

Digital preservation is of special importance in India due to its cultural diversity. Over time, the tribal communities have preserved their varied languages, oral history, artisanal skills, performance traditions, ecological knowledge and social customs. This is reflected in the growing institutional interest shown by the government initiatives. The Ministry of Culture has recorded information on the preservation and promotion of indigenous or tribal languages and cultural heritage such as documentation, literary programmes, folk or tribal literature projects, training in traditional arts, and inventory of intangible cultural heritage. Other, more recent, programs have also addressed tribal languages and museums. The Ministry of Tribal Affairs, in 2026 announced a national program on tribal language and museums with focus on documentation, preservation and revitalization. Such programs suggest that digital technology can be integrated into an overall cultural preservation program. However, the development of technology should always be linked to the involvement of the community, the local institutional system, and the educational system and living cultural practices.

5. CONCLUSION

The link between cultural identity and indigenous heritage is strong and indigenous traditions, languages, knowledge systems, artistic expressions and collective memories are part of the sense of belonging and continuity for communities. The study suggests digital technologies have a significant contribution to make in documenting and passing on this heritage via digital

ISBN Number: 978-93-88136-57-0

documentation, via audiovisual archives, via online platforms, via language-learning resources and digital educational materials. These technologies are especially useful to younger generations in connecting to their culture and can raise the awareness of indigenous heritage beyond geographic boundaries. The process of digitalisation, however, does not guarantee the preservation of living culture; cultural heritage is held by people, in their practice and their social relations, from one generation to the next. There can also be concerns about commercialisation, misrepresentation, privacy and loss of community ownership, and potential for uncontrolled digitisation. Thus, the successful preservation of indigenous heritage in the digital age demands a judicious and responsible use of technology that enhances, rather than displaces, living cultures. By actively engaging with the community, protecting TK and cultural sensitivity, and ensuring digital inclusion, a digital preservation framework can help ensure that indigenous heritage continues to evolve and is culturally relevant for future generations.

5.1 Recommendations

The study results have led to the following recommendations:

1. **Promote community participation:** It is important to involve indigenous communities, elders, cultural practitioners and youth in the planning, documentation, management and dissemination of their cultural heritage.
2. **Develop community-owned digital archives:** Digital repositories should be built in a manner that enables indigenous people to play a role in management and control of the cultural materials.
3. **Protect sensitive cultural knowledge:** Sacred, confidential or restricted cultural knowledge should not be captured and digitised or be made public without proper community consent and cultural protocol.
4. **Strengthen indigenous language preservation:** Development of indigenous language dictionaries, language learning applications, recorded oral traditions, multilingual educational resources, online language platform development should be encouraged to support endangered indigenous languages.

ISBN Number: 978-93-88136-57-0

5. **Improve digital literacy:** Indigenous youth and cultural practitioners need to be trained in digital documentation, audiovisual recording, archiving, editing and in managing digital resources.

REFERENCES

1. *Ajani, Y. A., Oladokun, B. D., Olarongbe, S. A., Amaechi, M. N., Rabiu, N., & Bashorun, M. T. (2024). Revitalizing indigenous knowledge systems via digital media technologies for sustainability of indigenous languages. Preservation, digital technology & culture, 53(1), 35-44.*
2. *Dutta, U. (2019). Digital preservation of indigenous culture and narratives from the global south: In search of an approach. Humanities, 8(2), 68.*
3. *Conti, L. (2025). Understanding culture, cultural identity, and cultural heritage in the post-digital age. Belonging in culturally diverse societies: Official structures and personal customs, 65.*
4. *Qureshi, A., Wilson, D., & Sarantou, M. (2025). Indigenous communities re-interpreting and preserving cultural heritage through narratives while navigating the digital age. In Digital Indigenous Cultural Heritage (pp. 121-143). Cham: Springer Nature Switzerland.*
5. *Shiri, A., Howard, D., & Farnel, S. (2022). Indigenous digital storytelling: digital interfaces supporting cultural heritage preservation and access. International Information & Library Review, 54(2), 93-114.*
6. *Singh, B., & Kumar, A. (2024). Examining the impact of digitalization on indigenous cultural heritage preservation in India. Enigma in Cultural, 2(1), 43-57.*
7. *Taylor, J. L., Soro, A., Roe, P., Hong, A. L., & Brereton, M. (2018). From preserving to performing culture in the digital era. In Digitisation of culture: Namibian and international perspectives (pp. 7-28). Singapore: Springer Singapore.*
8. *Kiftiyah, M., & Fitria, M. (2025). The role of digital technology in preserving local culture by indigenous communities amidst globalization. Bidayat: Journal of Islamic Law, 1(1), 144-160.*

ISBN Number: 978-93-88136-57-0

9. *Malik, H., & Farooq, M. (2025). African Culture and Indigenous Identity: Reclaiming Traditions in a Globalized Digital Age.*
10. *Zulkarnain, M. A. B. (2024). The Dynamics of Globalization and Local Cultural Identity: Challenges, Opportunities, and the Role of Digital Technology in Cultural Preservation. Bulletin of Science, Technology and Society, 3(1), 71-77.*
11. *Gafurova, V., Balynskaya, N., Koptyakova, S., Chuprin, V., & Shkurko, N. (2022). Problems of preserving the cultural heritage of the indigenous peoples of the North in the conditions of digitalization. In SHS Web of Conferences (Vol. 134, p. 00076). EDP Sciences.*
12. *Manžuch, Z. (2017). Ethical issues in digitization of cultural heritage. Journal of Contemporary Archival Studies, 4(2), 4.*
13. *Zhou, Z. (2025, March). Cultural Identity Preservation amid Globalization and Digitalization: Challenges, Transformations, and Digital Strategies. In CPS Digital Library-Series of Conferences (pp. 6-9).*
14. *Bihari, S. (2023). Cultural heritage and indigenous knowledge: Reviving traditions for future generations. Sustainable development goals in SAARC countries: Key issues, opportunities and challenges, 1(12), 24-32.*
15. *Alivizatou-Barakou, M., Kitsikidis, A., Tsalakanidou, F., Dimitropoulos, K., Giannis, C., Nikolopoulos, S., ... & Grammalidis, N. (2017). Intangible cultural heritage and new technologies: challenges and opportunities for cultural preservation and development. Mixed reality and gamification for cultural heritage, 129-158.*

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ARTIFICIAL INTELLIGENCE-DRIVEN PERSONALIZED FINANCIAL MARKETING AND ITS IMPACT ON FINANCIAL INCLUSION AND CUSTOMER ENGAGEMENT

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Abstract

Artificial Intelligence (AI) has revolutionised the financial services sector by facilitating data-informed decision-making, sophisticated automation, and tailored consumer experiences. This study investigates the impact of Artificial Intelligence Adoption and Personalised Financial Marketing on Financial Inclusion and Customer Engagement. A quantitative study design was utilised, and primary data were gathered from 130 users of digital financial services via a structured questionnaire employing a five-point Likert scale. The gathered data were examined utilising descriptive statistics and simple linear regression in IBM SPSS Statistics. The results indicate that both the adoption of Artificial Intelligence and Personalised Financial Marketing positively and significantly influence Financial Inclusion and Customer Engagement. Personalised Financial Marketing shown a notably greater impact, suggesting that individualised financial communication and bespoke product suggestions are essential for improving consumer engagement and fortifying enduring connections with financial institutions. The research emphasises that the amalgamation of AI technology with customer-focused marketing tactics can enhance accessibility, service quality, and engagement, hence fostering greater financial inclusion. The results offer actionable insights for banks, fintech firms, marketers, and politicians to create innovative, ethical, and inclusive digital financial systems that foster sustainable growth and augment customer value in a progressively digital economy.

Keywords: Adoption of Artificial Intelligence, Personalised Financial Marketing, Financial Inclusion, Customer Engagement, Digital Financial Services, FinTech, Customer-Centric Marketing.

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1. Introduction

In the financial services sector, Artificial Intelligence (AI) stands out as a technology that has significantly transformed the industry by enabling organisations to improve their efficiency, decision making and customer experiences. AI is a term used to describe the utilization of advanced technologies like machine learning (ML), natural language processing (NLP), deep learning, and generative artificial intelligence (GenAI) to manipulate vast sets of information, identify patterns, forecast, and automate intricate processes. While software mechanisms work with predetermined code, AI mechanisms learn and adapt over time, from the data. With this functionality, financial institutions can get valuable insights, streamline operations, and offer targeted financial solutions to customers.

Financial services, such as banking, insurance, capital markets, and payment systems, are one of the initial fields to apply AI technologies since they deal with vast amounts of data generated daily and a growing demand for efficiency and regulatory compliance in their operations. AI is being used by financial institutions to automate repetitive tasks, improve fraud detection systems, strengthen risk management strategies, and boost customer engagement strategies. By leveraging AI-powered tools, companies can make informed decisions to optimize their operations, boost productivity, and discover fresh revenue streams, thereby lowering costs and enhancing overall business performance. With digital transformation continuing to transform the financial landscape, artificial intelligence (AI) is a crucial element in today's financial ecosystems.

Furthermore, AI has played an important role in enhancing customer experiences by providing personalized recommendations, intelligent chatbots, and tailored financial services. AI can be used to understand customer behavior, transaction history, and preferences, allowing businesses to deliver highly personalized services. While AI's many benefits are undeniable, it also has significant concerns regarding data privacy, algorithmic bias, explainability, cybersecurity, and regulatory compliance. As a result, the need to strike a balance between innovation and ethical and regulatory concerns persists for sustainable implementation of AI in financial services (V., 2026).

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A. Evolution of AI in the Financial Sector

AI's journey in finance has been marked by a gradual shift from rudimentary automation to advanced intelligent systems with autonomous decision-making capabilities. Financial institutions in the 1980s and the early 2000s used rule-based expert systems which were based on a set of logically defined "if-then" rules. Basic tasks performed with these systems included transaction processing, reconciliation, tax planning and financial analysis. They were great to automate the same repetitive tasks, but they were not able to learn from data or to adapt to changing environments.

Machine learning technologies has become a major change in the 2010s. With the improved computing power, cloud technology, and big data analysis, financial institutions could handle large volumes of structured and unstructured information. Algorithms and machine learning boosted credit rating models, fraud detection capabilities and risk assessment predictive analytics. It was also a time when algorithmic trading platforms and robo-advisory services rose to prominence, enabling investors to tap into automated investment management solutions powered by data-driven insights (Malay Sarkar & Sanjida Rahman, 2025).

With the development of deep learning in the late 2010s and early 2020s, financial companies started using neural networks to handle intricate information, such as text, images, and client interactions. Natural language processing enabled intelligent chatbots, virtual assistants and sentiment analysis tools to understand customer emotions and human language. These developments helped customers' service, enhanced risk management, and allowed better financial forecasting.

In recent years, the field of generative AI and agentic AI systems has seen tremendous growth. Generative AI technologies can generate content, reports, help with coding, and have natural conversation interactions. Agentic AI further enhances these capabilities by enabling autonomous execution of multi-step processes, coordination of tasks and making contextual decisions. These technologies are now increasingly being used by financial institutions to monitor compliance, prevent fraud, provide personalised financial advisory services and for real-time operational management. With AI continuing to advance, it is becoming more than just a set of individual

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tools – it is a strategic enterprise-wide capability that can generate innovation and competitive advantage (Paramesha et al., 2024).

B. AI-Driven Transformation of Financial Operations and Marketing

The operational processes and marketing activities in financial institutions are being revolutionized by Artificial Intelligence. AI improves efficiency in financial operations by automating repetitive and time-consuming tasks like data entry, transaction reconciliation, reporting, forecasting and document processing. Combining AI and Robotic Process Automation (RPA) streamlines operations, reduces manual effort, and reduces errors. These enhancements allow businesses to realize significant reductions in cost and boost productivity and service (Aldasoro et al., 2025).

One of the most powerful and impactful uses of AI in financial operations is risk management and fraud detection. Unlike traditional systems, machine learning models can detect anomalies and suspicious activities because they can analyze transactions in real time. The AI algorithms can adapt and learn from new fraud trends to arm institutions with effective security measures and help them avoid financial loss. Likewise, AI-powered credit scoring systems leverage alternative data sources, such as transaction patterns and digital footprints, to enhance creditworthiness evaluations and open bank loans to a wider population, boosting financial inclusion (Pattanayak, 2021).

AI also plays a crucial role in regulatory compliance and portfolio management. Compliance systems are automated and track transactions, identify compliance breaches and report them to supervisory authorities as necessary. AI-powered trading systems and robo-advisors in investment management can analyze market trends, forecast price movements, and optimize portfolio allocation strategies. These are the features that allow financial institutions to mitigate risk better and improve investment performance.

When it comes to marketing and customer engagement, AI can enable incredibly targeted interactions, leveraging customer data such as their demographics, preferences, financial activities, and transaction history. Financial institutions can better categorize customers and offer personalized financial advice, product recommendations, and promotional offers. AI-driven

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chatbots and virtual assistants offer 24/7 customer support, enhance responsiveness and customer satisfaction, and cut costs in the service.

Moreover, generative AI can be used to create marketing content, optimize campaigns, and guide communication strategies with customers. AI can help marketers adapt their strategies in real time, based on the predicted reaction of their customers, and maximize engagement. Hyper-personalized experiences across multiple digital channels help create customer loyalty, enhance retention and create new revenue channels. Thus, AI has emerged as a pivotal technology for enhancing operational efficiency and delivering customer-focused solutions in the financial sector (DR. S.JEYAKUMAR, 2025).

1.1. Research Objectives

- To explore how the adoption of Artificial Intelligence affects Financial Inclusion and Customer Engagement.
- To assess the impact of PFM on Financial Inclusion and Customer Engagement.

1.2. Need of the Study

The financial industry has undergone significant transformation as it becomes increasingly digital, impacting the way financial institutions communicate with customers. AI (Artificial Intelligence) is a transformative technology that has the potential to enhance operational efficiency, automate financial processes and provide personalized financial services. At the same time, customized financial marketing has helped businesses gain insight into customer needs and preferences, make personalized product suggestions, and boost customer experience. While these developments have been significant, there remain many people who are still excluded from access to formal financial services, and financial institutions who have difficulties in retaining their customers' attention over time. Thus, the combined impact of AI adoption and personalized financial marketing on enhancing financial inclusion and customer engagement needs to be explored.

Furthermore, the existing studies have mostly focused on the adoption of AI, services provided by fintech, or financial inclusion alone, and there has been little empirical evidence that includes the adoption of AI and tailored financial marketing as co-determinants of financial inclusion and

ISBN Number: 978-93-88136-57-0

customer engagement. This study aims to fill this gap in the research literature, and examines the interaction of these variables in financial services. The results will offer pragmatic recommendations for banks, fintech firms, financial policymakers, and financial marketers in developing customer-focused, tech-driven strategies to enhance service accessibility, customer satisfaction, and inclusive and impactful financial development while helping to drive sustainable digital transformation.

2. Literature review

(Ma, 2024) The financial services industry has seen a rapid pace of information technology growth, and big data is among the key tools in personalized marketing. This paper examines the use and effects of personal marketing strategies for financial products in the present economic context, based on big data analysis. Financial institutions can develop customer profiles and custom-made products and services based on their analysis of consumers' buying habits, behavioral preferences, social networks and interactive feedback. We explored more deeply how financial institutions can use big data to better streamline marketing, design their products to fit customers needs, enhance customer satisfaction and foster loyalty through a range of research strategies and tools, such as case studies, in-depth interviews and quantitative analysis. Big data has proven to be a significant asset for the marketing of financial products, for better market segmentation, for offering more cross-selling and value-added services, and for optimising marketing resources by predictive analytics, instant marketing and very personalized customer experiences. However, financial institutions need to possess strong capabilities in data management, analysis technology, data privacy and personalized marketing strategies to truly harness these benefits.

(Apriadi et al., 2025) The development of financial technology (fintech) has revolutionized the way people access, manage and make decisions in personal finance. The digitization of financial services not only offers convenience and efficiency, but also triggers significant changes in people's economic behavior, especially among the younger generation and urban groups. The objective of this study is to systematically analyse the impact of financial technology on the economic behavior of individuals with regard to consumption, investment and

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financial planning. The approach followed is the systematic review of the scientific literature on the subject from 2018 to 2025. Results indicate that financial technology has a positive influence on increasing digital financial literacy, saving and investment practices and facilitating financial decision-making. It also comes with some drawbacks like increased impulsive consumption thanks to digital credit's features and inequity in the adoption of technology between urban and rural communities. The findings of this study highlight the need to enhance inclusive financial literacy and consumer protection measures as foundations for building a safe and sustainable digital financial ecosystem.

(Mishra et al., 2025) In this chapter, the implications of Artificial Intelligence (AI) technologies for customer relationship in finance are examined. The chapter opens with a subtopic on intelligence-driven financial engagement and explains the opportunity that clients have in the form of AI to provide specific solutions for their needs. It then goes on to discuss important aspects like natural language processing (NLP), machine learning, and how their use can help narrow its focus on customer interactions and relevant customer data. The chapter provides an overview on how AI can help in crafting personalised financial promotional offers and enhance consumer relationships and customer service delivery. Lastly, the foresight of future developments elucidates the function of future developments, that is, the trends which will aid in engaging the customers in the financial industry when it comes to AI technologies, in a wide spread context. We have gained insights on the role AI plays in making the financial industry more client-focused, efficient, and responsible.

(Mhlanga, 2023) The aim of this study is to critically examine the issues that come with the use of AI solutions in financial inclusion of the excluded. The study identified through unobtrusive research methods such as conceptual and documentary analysis, that while leveraging AI in financial inclusion through digital tools brings numerous opportunities, it also comes with its share of challenges. Despite the advantages, the study found that the use of AI in the inclusion of the excluded households is linked to various problems such as consumer protection issues, data protection and cyberattacks. Additional hurdles such as the loss of competition, reckless use of AI and the danger of exacerbating the digital divide, exclusion and displacement are all risks to

ISBN Number: 978-93-88136-57-0

consider. Thus, the study concludes that digital infrastructure is one of the pillars of the economic and social development policies must be emphasized by the policy makers in collaboration with private sector, so as to facilitate the participation of the excluded people. The development of digital infrastructure should be one of the foundations of the economic and social development plans which will make it easy for those excluded to be able to participate fully. Furthermore, this will help to a great extent in tackling many challenges that are associated with inadequate infrastructure.

(Sharma & Priya, 2025) AI's impact on Financial Technology (FinTech) services has revolutionized the way financial products and services are delivered, opening the doors to greater financial inclusion and financial wellbeing. This study examines how AI features and mindfulness affect the financial wellbeing, financial inclusion and service quality perceptions of the FinTech users in North India. The data were gathered from 469 respondents across three generations (Generation X, Millennials, and Generation Z) using both online and offline surveys. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used for the study to analyze the relationships between AI adoption, IT mindfulness, technological self-efficacy, financial self-efficacy, user expectations, behavioral intention, and FinTech usage. The results show that the use of AI has a positive impact on several key constructs, such as IT mindfulness, technological self-efficacy, and financial self-efficacy, with these factors positively influencing performance expectancy, effort expectancy, and hedonic motivation. IT mindfulness has a positive effect on performance expectancy and effort expectancy as well, although less potent with regards to hedonic motivation. Moreover, the results show that technophobia has a negative moderating effect on the relationship between behavioral intention and actual FinTech usage, suggesting that fears about technology usage may pose a threat to the realization of the benefits of AI. The results further demonstrate that increased FinTech usage leads to greater financial well-being and financial inclusion. The findings underscore the need for user-focused AI solutions, robust security measures, ethical governance, and effective communication strategies to alleviate technophobia, foster trust, and ensure the social and economic benefits of AI-powered FinTech services are realized.

ISBN Number: 978-93-88136-57-0

3. Research Methodology

3.1.Research Design

The study used a quantitative, descriptive, and explanatory research design to examine the impact of the adoption of Artificial Intelligence and personalization of financial marketing on financial inclusion and financial customer engagement. A cross sectional survey research method was used to gather data at one point in time, and thus to assess the relationships among the study variables. It can be used for customer perception studies and analysing effects of technological and marketing practices in financial services.

3.2.Population and Sampling

The target population included customers of banks and fintech platforms who have used digital financial services and have had experience with financial services using AI and personalized financial marketing. Respondents were selected using a convenience sampling technique due to the ease with which samples were gathered of individuals who were accessible within the available time and resources. 130 valid responses were gathered and analyzed statistically.

3.3.Data Collection

A structured questionnaire along the lines of a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) was used for the collection of primary data. The questionnaire composed demographic questions and measuring items of Artificial Intelligence Adoption, Personalized Financial Marketing and financial Inclusion and Customer Engagement. For wider participation and better quality of responses, the survey was conducted in both online and offline format.

3.4.Data Analysis Techniques

Collected data were coded and analyzed by the software program IBM SPSS Statistics. Descriptive statistics such as frequencies and percentages were used to provide a summary of the demographic characteristics of the respondents. Simple Linear Regression Analysis was used for the analysis of the relationship between Artificial Intelligence Adoption and Personalized Financial Marketing on Financial Inclusion and Customer Engagement. The regression models were tested for significance

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at 5% level ($p<0.05$) by Model Summary, ANOVA and Coefficient analysis. Through this analytical procedure the study was able to ascertain the force, direction and statistical significance of the interaction between the variables.

4. Result

Table 1: Age

Age		
	Frequency	Percent
18–25 years	24	18.5
26–35 years	27	20.8
36–45 years	30	23.1
46–55 years	20	15.4
Above 55 years	29	22.3
Total	130	100.0

The age distribution of the 130 respondents shows that there is a good spread of ages. Participants were aged 36 to 45 with the largest group being 30 (23.1%), indicating that the majority of the participants were middle aged. This was followed by the ‘Above 55 years’ age group with 29 respondents (22.3%) and the ‘26-35 years’ age group with 27 respondents (20.8%). The largest group of respondents were in the age range of 18 to 25 years with 24 respondents (18.5%) and the smallest group was the age group of 46 to 55 years with 20 respondents (15.4%). In general, the results show that the study is representative of different age groups, with a wide representation of participants, and thus, there is less chance of age-related bias in the study analysis.

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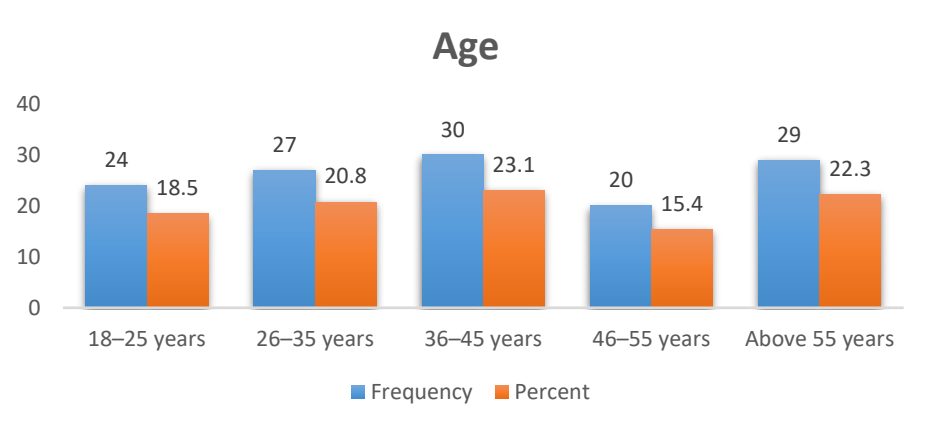


Figure 1: Graphical presentation of age responses distribution

Table 2: Gender responses distribution

Gender		
	Frequency	Percent
Male	69	53.1
Female	61	46.9
Total	130	100.0

The gender-wise distribution of the respondents indicates a fairly even distribution of the respondents in the study sample. 69 out of the 130 respondents were male (53.1%) and 61 respondents were female (46.9%). The number of males was slightly greater than the number of females, but this does not represent a significant difference between the two, suggesting that both genders were equally represented. This balanced distribution increases the credibility of the research as it reduces gender sampling bias and ensures that the results reflect from both men and women. The demographic profile, therefore, enables a comprehensive analysis of the perception of artificial intelligence, personalized financial marketing, financial inclusion and customer engagement by gender.

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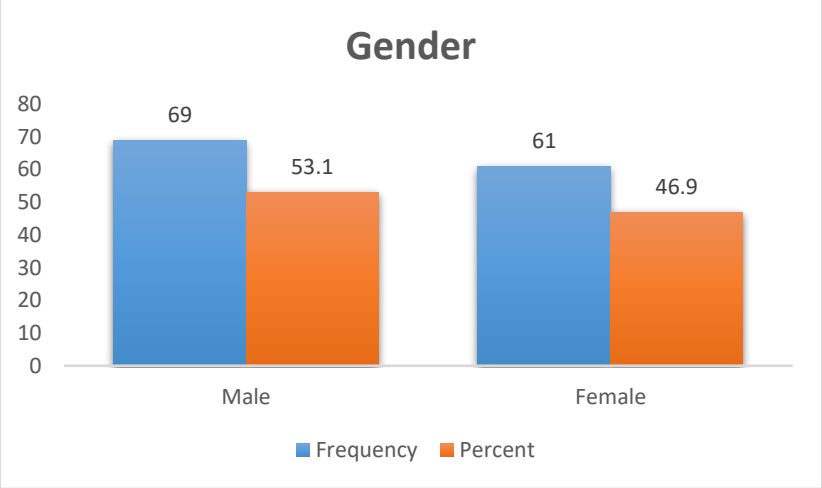


Figure 2: Graphical presentation of Gender responses distribution

Table 3: Educational qualification responses distribution

Educational Qualification		
	Frequency	Percent
Higher Secondary or Below	22	16.9
Diploma	20	15.4
Graduate	34	26.2
Postgraduate	30	23.1
Doctorate	24	18.5
Total	130	100.0

The educational qualification of the respondents marks a wide academic spectrum of the study sample. From the 130 persons who responded, the highest number 34 (26.2%) were Graduates while 30 (23.1%) were Postgraduates. Out of the 24 respondents with doctorate qualification, 18.5% and 16.9% of the respondents had Higher Secondary or Below qualifications respectively. Diploma holders (20 respondents or 15.4%) were the smallest category. The distribution shows that a significant share of respondents have more than a high school education, a sign of a relatively

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high level of education awareness, which could contribute to an understanding and acceptance of AI-powered financial services and personalised financial marketing strategies.

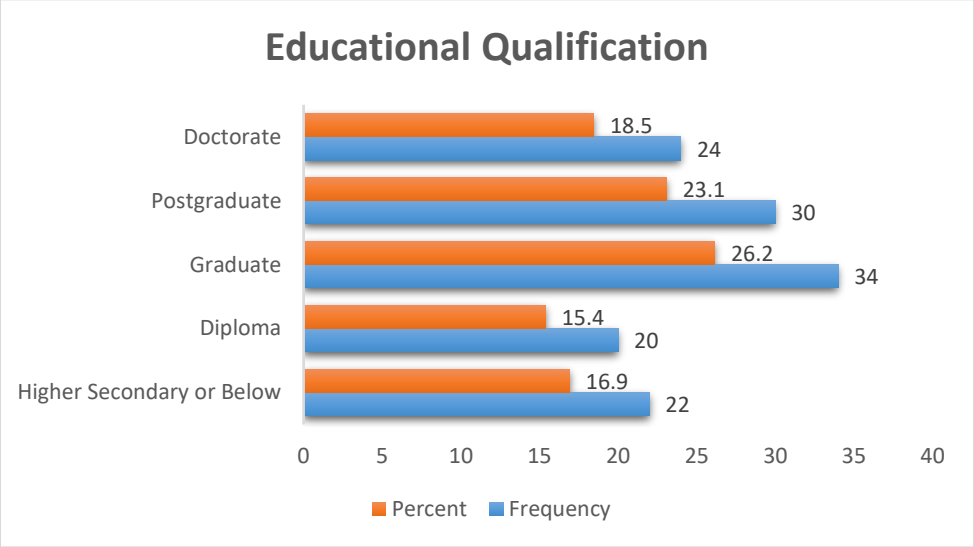


Figure 3: Graphical presentation of educational qualification responses distribution

Table 4: Preferred Digital Financial Platform qualification responses distribution

Preferred Digital Financial Platform		
	Frequency	Percent
Mobile Banking App	26	20.0
Internet Banking	29	22.3
UPI Applications	40	30.8
Digital Wallets	35	26.9
Total	130	100.0

The results for respondents' preferred DFP usage show different usage patterns. UPI Applications has been the most preferred platform with 40 respondents (30.8%), indicating the rising popularity of instant payment digital platforms. Digital Wallets was followed by Internet Banking, with 29

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respondents (22.3%) indicating that they used it. The smallest number of respondents, 26 (20.0%), preferred Mobile Banking Applications. The findings indicate that respondents had a higher preference for the payment offerings that are faster, convenient, and readily available, than the traditional banking payment methods. The trend indicates a growing trend toward embracing digital financial technologies, which is driven by the rising significance of AI-powered financial services for providing better customer convenience and engagement.

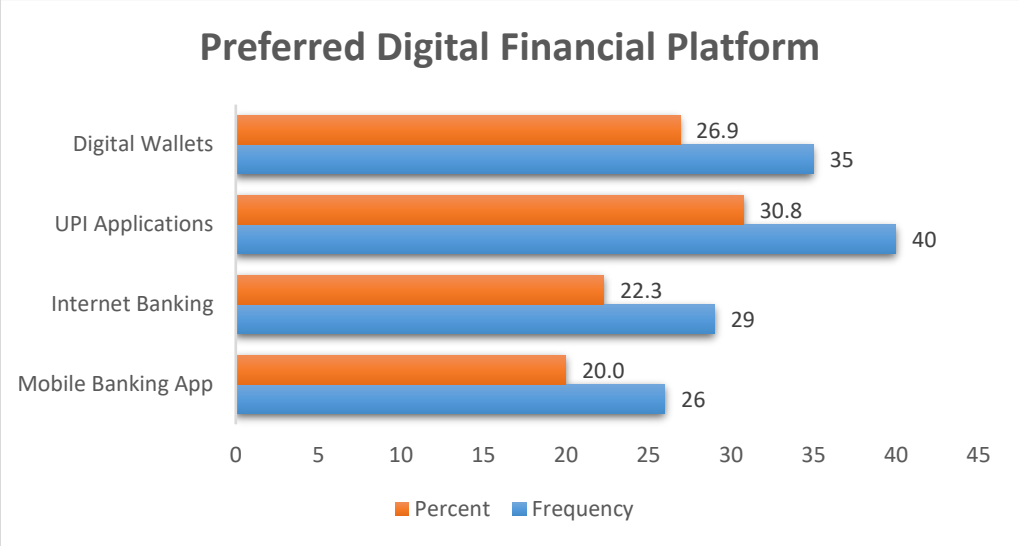


Figure 4: Graphical presentation of Preferred Digital Financial Platform qualification responses distribution

Table 5: Type of Financial Institution Mostly Used qualification responses distribution

Type of Financial Institution Mostly Used		
	Frequency	Percent
Public Sector Bank	33	25.4
Private Sector Bank	35	26.9
Cooperative Bank	35	26.9
FinTech Platform	27	20.8
Total	130	100.0

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The pattern of respondents by the main financial institution used to obtain their money was fairly even. The most common financial institutions used by the respondents were private Sector Banks and Cooperative Banks which accounted for 35 respondents (26.9%). A similar level of usage was observed with Public Sector Banks, with 33 respondents (25.4%) preferring them. In the smallest category, 27 respondents (20.8%) used FinTech Platforms. The results suggest that traditional banking institutions are still the predominant sources of finance for the respondents, but that digital finance platforms are also being used, albeit to a lesser degree. This balanced distribution could shed light into consumer preferences and indicate that traditional banks and new players from the fintech sector have complementary and important roles to play in supporting financial inclusion and customer engagement.

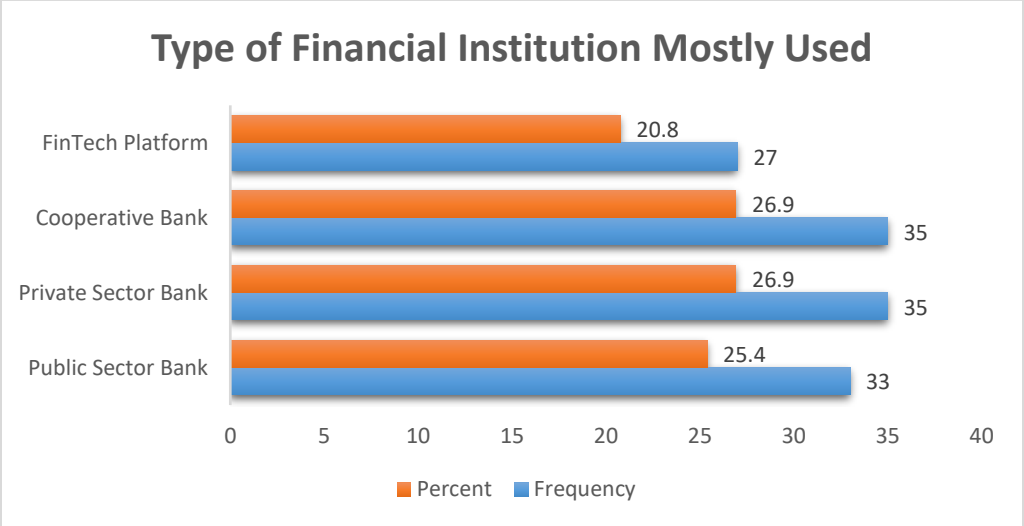


Figure 5: Graphical presentation of Preferred Digital Financial Platform qualification responses distribution

Hypothesis 1

Table 6: Linear regression Impact of Personalized Financial Marketing on Financial Inclusion and Customer Engagement

ISBN Number: 978-93-88136-57-0

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.363a	.132	.125	.992
a. Predictors: (Constant), Personalized Financial Marketing				

According to the Model Summary, there is a moderate positive correlation between the variables of Personalized Financial Marketing and Financial Inclusion and Customer Engagement with an R of 0.363. The R Square value of 0.132 indicates that the model accounted for 13.2% of the variability in the dependent variable, with the remaining 86.8% being explained by other factors not examined in the model.

ANOVAa						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.073	1	19.073	19.388	.000b
	Residual	125.919	128	.984		
	Total	144.992	129			
a. Dependent Variable: Financial Inclusion and Customer Engagement						
b. Predictors: (Constant), Personalized Financial Marketing						

The results of the ANOVA test showed that the regression model is statistically significant, an F value of 19.388 with a significant level of 0.000 ($p < 0.001$). Overall, Personalized Financial Marketing shows a significant impact on Financial Inclusion and Customer Engagement. Hence, the regression model is suitable and the model is meaningful to explain the relationship between the variables.

ISBN Number: 978-93-88136-57-0

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.951	.386		5.052	.000
	Personalized Financial Marketing	.425	.096	.363	4.403	.000
a. Dependent Variable: Financial Inclusion and Customer Engagement						

Results of the coefficient analysis indicate the positive and statistically significant relationship between Personalized Financial Marketing and Financial Inclusion and Customer Engagement, with $\beta = 0.363$, $B = 0.425$, and $p = 0.000$. This means that the higher the level of Financial Inclusion and Customer Engagement, the more improved Personalized Financial Marketing is. Therefore, the predictor contributes greatly to the regression model in a positive direction.

Hypothesis 2

Table 7: Linear regression Impact of Artificial Intelligence Adoption on Financial Inclusion and Customer Engagement

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.286a	.082	.075	1.020
a. Predictors: (Constant), Artificial Intelligence Adoption				

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According to the Model Summary, there is a positive relationship between Adoption of Artificial Intelligence and Financial Inclusion and Customer Engagement, there R value is 0.286. The R Square value of 0.082 suggests that the financial inclusion and customer engagement is 8.2% of the variance is explained by the Artificial Intelligence Adoption variable, and 91.8% is explained by other variables that are not presented in the regression model.

ANOVAa						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.852	1	11.852	11.394	.001b
	Residual	133.140	128	1.040		
	Total	144.992	129			
a. Dependent Variable: Financial Inclusion and Customer Engagement						
b. Predictors: (Constant), Artificial Intelligence Adoption						

Based on the ANOVA table, the model is statistically significant, as reported F value of 11.394 and significance value of 0.001 are statistically significant which is less than 0.05. This result suggests that the relationship between the two variables, Financial Inclusion and Customer Engagement, is well explained by using regression model since Artificial Intelligence Adoption has a significant effect on Financial Inclusion and Customer Engagement.

Coefficientsa						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.249	.412		5.455	.000

ISBN Number: 978-93-88136-57-0

	Artificial Intelligence Adoption	.359	.106	.286	3.376	.001
a. Dependent Variable: Financial Inclusion and Customer Engagement						

The Coefficients table shows that the Artificial Intelligence Adoption is positively and significantly associated with Financial Inclusion and Customer Engagement ($B = 0.359$, $\beta = 0.286$, $p = 0.001$). It means that as Financial Inclusion increases, AI Adoption goes up, and vice versa. So, the value of the independent variable (IV) is very significant and positive in the regression model.

5. Discussion

The results of this study shows that both the Personalized Financial Marketing and the use of Artificial Intelligence (AI) have significant impacts on Financial Inclusion and Customer Engagement, with the effect of AI being slightly stronger. The regression analysis showed that Personalized Financial Marketing is more positively influenced ($\beta = 0.363$, $p < 0.001$) than AI Adoption ($\beta = 0.286$, $p = 0.001$), suggesting that customized financial communication, tailored product suggestions, and targeted marketing approaches have a greater impact on enhancing customer participation and engagement in financial services. The results align with the increased focus on customer-centric marketing strategies across the financial industry and recent data indicating that the use of AI-driven personalization improves customer engagement, campaign performance, and customer relationship management.

The results also show that Personalized Financial Marketing accounts for 13.2% of the variance in Financial Inclusion and Customer Engagement, while AI Adoption accounts for 8.2%. While relatively weak, these are indications that both variables are significant predictors and that other technological, behavioral and institutional factors play a role in customer engagement. Adopting AI has shown positive impacts, which aligns with previous research demonstrating that AI-powered chatbots, predictive analytics, and intelligent recommendation systems enhance accessibility, service quality, and customer experiences in financial institutions. Concurrently, the

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limited level of explanatory value of the use of AI means that technology will not be enough if it is not combined with suitable personalization elements and customer-centric service provision.

The study emphasizes that AI should be seen as a tool to aid banks, not a standalone solution. AI's capabilities, when united with personalized financial marketing, can enhance customer engagement, broaden access to financial services, and promote financial inclusion. Implementing such a system, however, demands an approach of tackling data privacy, transparency, ethical AI practices, and fostering customer trust, ensuring sustainable adoption and long-term value creation.

6. Conclusion

Consequently, it is concluded that the influence of Artificial Intelligence Adoption and Personalized Financial Marketing to Financial Inclusion and Customer Engagement positively and significantly in the financial services sector. The regression analysis showed that both independent variables are statistically significant variables in the analysis of the dependent variable, with the influence of Personalized Financial Marketing with relatively larger than the influence of AI Adoption. The results suggest that in addition to optimizing operations, predictive analytics, and intelligent customer interactions, AI also has a more direct impact on the customer experience and fostering the adoption of formal financial services through personalized marketing strategies. The study also underscores the potential of AI technologies in financial services to provide personalized financial offerings, enhance customer service reach and deepen customer relationships, which are central to customer-centric marketing strategies. The limited explanatory power of the regression models, however, indicates that other technological, behavioral and institutional factors are also linked to the level of financial inclusion and customer engagement. Overall, the study highlights the importance of financial institutions embracing AI-driven innovation while maintaining ethical data handling, transparency, and tailoring customer experiences to provide maximum value to their customers and foster inclusive digital finance. The results offer valuable insights for banks, fintech firms, marketers, and regulators aiming for sustainable digital transformation and financial inclusion.

ISBN Number: 978-93-88136-57-0

7. Suggestions

- Onboard cutting-edge AI capabilities to deliver customer-focused and accurate financial services in a timely manner.
- Improve customer-centric financial marketing strategies through data analytics and behaviour.
- Promote digital financial literacy by awareness raising on the use of financial services with AI components.
- Improve data privacy, cyber security and ethical AI governance to build customer trust & confidence.
- Create financial products that are accessible and inclusive for those who have been left out of the financial system and in rural areas.
- Integrate AI-powered chatbots and virtual financial advisors to provide continuous customer support and personalized assistance.
- Provide incentives for banks, fintech firms and regulators to foster innovation while maintaining regulatory integrity.
- Regularly review and update AI utilization and customer engagement, fostering sustainable financial inclusion practices.

References

1. *Aldasoro, I., Gambacorta, L., Korinek, A., Shreeti, V., & Stein, M. (2025). Intelligent financial system: How AI is transforming finance. Journal of Financial Stability. https://doi.org/10.1016/j.jfs.2025.101472*
2. *Apriadi, D., Adelin, D., Mutumanikam, P. R., & Lanjarsih, L. (2025). Personal Finance Transformation in the Digital Era: The Impact of Financial Technology on People's Economic Behavior. Oikonomia : Journal of Management Economics and Accounting. https://doi.org/10.61942/oikonomia.v2i3.356*
3. *DR. S.JEYAKUMAR. (2025). THE IMPACT OF AI: ADVANCING ACCURACY AND EFFICIENCY IN THE BANKING INDUSTRY. International Research Journal of Education and Technology.*

4. *Ma, Y. (2024). Research on Personalized Marketing Strategy of Financial Products Based on Big Data. SHS Web of Conferences, 200, 01014. https://doi.org/10.1051/shsconf/202420001014*
5. *Malay Sarkar, & Sanjida Rahman. (2025). Artificial Intelligence in Modern Banking: Revolutionizing Financial Services, Risk Management and Customer Experience. World Journal of Advanced Engineering Technology and Sciences, 16(2), 260–270. https://doi.org/10.30574/wjaets.2025.16.2.1289*
6. *Mhlanga, D. (2023). Artificial Intelligence (AI) Solutions for Financial Inclusion of the Excluded: What Are the Challenges? In Advances in African Economic, Social and Political Development. https://doi.org/10.1007/978-3-031-31431-5_14*
7. *Mishra, S., Joshi, A., & Lakshmi, D. (2025). Transforming the financial market using AI generated personalized content. In Intersecting Natural Language Processing and FinTech Innovations in Service Marketing. https://doi.org/10.4018/979-8-3693-9944-6.ch024*
8. *Paramesha, M., Rane, N., & Rane, J. (2024). Artificial intelligence, machine learning, deep learning, and blockchain in financial and banking services: a comprehensive review. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4855893*
9. *Pattanayak, S. K. (2021). The Impact of Artificial Intelligence on Operational Efficiency in Banking: A Comprehensive Analysis of Automation and Process Optimization. International Research Journal of Engineering and Technology.*
10. *Sharma, V., & Priya, B. (2025). Bridging the gap: AI-powered FinTech and its impact on financial inclusion and financial well-being. Discover Artificial Intelligence. https://doi.org/10.1007/s44163-025-00465-9*
11. *V., S. S. (2026). "Impact of Artificial Intelligence and Machine Learning on Personalized Financial Services in Banking and Insurance." Research Gate. https://www.researchgate.net/publication/400907486_Impact_of_Artificial_Intelligence_and_Machine_Learning_on_Personalized_Financial_Services_in_Banking_and_Insurance.*

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ANALYZING EDUCATIONAL AND ACADEMIC CHALLENGES FACED BY STUDENTS IN MODERN LEARNING ENVIRONMENTS

Imtiaz Khan
Research Scholar

ABSTRACT

Technology integration is increasingly impacting contemporary learning spaces, which offer greater flexibility, accessibility, and engagement. Students do, however, also face academic challenges, including difficulty in maintaining motivation and focus 40% of the time, poor supervision 25% of the time, and high stress due to workload pressures 20% of the time. A descriptive survey research design is employed in this study to investigate the impact of academic challenges, institutional support, and technology on students' learning experience. Data was collected using an online survey, and descriptive statistics were applied for analysis. As per research, 20% of students experience difficulty with distractions and technological issues, while 65% of students find technology useful. While they are instrumental in solving these problems, institutional support systems such as academic guidance and mental health facilities are merely moderately effective—only 40% of the students feel they get sufficient mental health assistance. To ensure a more inclusive and effective learning process, the research underlines the need for well-balanced digital learning approaches, improved teacher-student interactions, and increased institutional support services. Schools can foster student success and well-being in dynamic learning environments by addressing these problems.

Keywords: Student Engagement, Technology Integration, Academic Challenges, Institutional Support, Modern Learning Environments.

1. INTRODUCTION

Social interactions, organizational structures and cultures, and the actual and virtual spaces that shape and influence students' experiences, perceptions, and learning are all encompassed in the term "educational environment." To improve student learning outcomes, the educational

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environment can be modified and is quantified. A key indicator for enhancing the quality of education is the assessment of students' perceptions of the learning environment. Students' motivation could be significantly affected by the nature of an educational environment, which either encourages or discourages them from taking part in the learning process. Consequently, the idea of students' participation in learning is not rigid but shaped by the students' learning experience. The perceptions of students of the learning environments in medical schools and other institutions of health professions education can be measured using the Dundee Ready Education Environment Measure (DREEM) questionnaire. Thirty years ago, the DREEM was constructed by a Delphi panel consisting of scholars from global medical schools and health professionals. It was then piloted on students in some other countries to establish its validity. Since a valuable instrument to measure the learning environment in undergraduate health professions education programs, much attention has been attracted to this inventory.

Student engagement refers to the active participation of students in academic and extracurricular learning, teaching, research, government, and community activities. Student engagement, as used in education, is the state of mind through which students are able to be motivated, work diligently, and engage fully in the process of learning. The most commonly applied theoretical framework for conceptually understanding student engagement defines it as a concept that incorporates aspects of behavior, emotions, and cognition. Cognitive investment in learning that happens when students do more than just fulfill standards, savor challenges, and direct their efforts toward applying deep and metacognitive approaches to understand and master the subject is referred to as cognitive engagement. Perseverance, task completion, active engagement, questioning, directed attention, and school activity involvement are some examples of positive behavior that reflect behavioral engagement. Emotional reactions to the school, teachers, or classroom, including pleasure, happiness, and curiosity, are termed emotional involvement.

Students who take HPE cite a range of academic and personal benefits. Although often having a small effect size, student engagement—particularly cognitive engagement—is positively related to academic achievement. The observation that student engagement does not always map onto GPA or test scores, however, indicates that its benefits may be more apparent in non-quantitative

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domains of student achievement. Furthermore, student engagement lowered students' HPE burnout, especially its emotional and behavioral forms, by much. Student engagement also improved students' welfare and happiness with learning. Good mental health, for example, decreased depression and improved life satisfaction. Aside from the impact it has on particular students, student engagement is important as it makes instruction simpler through amplifying teachers' intrinsic motivation. Teacher burnout, on the other hand, was greatly influenced by student disengagement.

2. REVIEW OF RELATD LITERATURE

Archambault et al. (2022) addressed the five pillars that underpin online pedagogy, all of which emanate from principles of contextual learning, constructivism, and learner-centeredness. Teachers are challenged today by virtue of the expansion of the demand for online education, such as the capacity to combine subject matter knowledge with lively teaching methods in harnessing gains from technological revolution. Online pedagogy thus gained prominence within contemporary classrooms. The challenge is in understanding the nature of online teaching, the skills needed from teachers to be successful in virtual settings, and the theoretical frameworks underpinning the significance of these skills. Establishing relationships and a community, such as active learning, employing learner agency, adopting mastery learning, and individualizing the learning process are some of these pillars. We describe their theoretical underpinnings, review pertinent literature, and consider how they could influence teacher preparation, which could, in turn, influence research in the learning sciences, educational psychology, and educational technology.

Alam, A. (2022) discussed the possible educational applications of social robots, pedagogical and technological challenges they pose, and the possible impact they might have on learning outcomes, with exclusive emphasis on robots intended to assist students in learning through social interaction. Three salient research questions were identified by the author: 1) Can robot tutors improve students' learning outcomes? 2) Does the look and conduct of a robot impact students' learning significantly? 3) What are the potential roles a robot can play in a learning context? The author's assertions are substantiated through a statistical meta-analysis of previously published research

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studies. The overall aim of this article is to successfully establish the groundwork for future research by describing the predicted outcomes of utilizing social robots as a means to deliver instruction and identifying potential avenues for further study.

Kolgatin et al. (2022) examined the challenges faced by students studying independently outside of class in a cloud-based information and communication learning environment. To develop the courseware "Educational Electronic Resources for Primary School" for future primary school teachers, the research conducted a survey of students at a pedagogical university. More detailed instructions on work completion, a lack of motivation, and a lack of familiarity with self-management were found to be the major barriers. Students emphasized the importance of careful time management and proposed providing assignments with detailed written or verbal instructions. Conditions for managing students' independent work outside the classroom in a cloud learning environment were formulated as a result of the analysis of students' learning activities and achievements during the COVID-19 pandemic by the study.

Munna and Kalam (2021) studied a variety of scholarly articles, teaching methods, and inclusive approaches to determine the effectiveness of teaching within the environment of a higher education institution. Transferring knowledge from teachers to students is referred to as teaching and learning. It is the culmination of a number of elements in the process through which a teacher formulates and sets learning objectives, develops instructional materials, and implements the teaching and learning approach. Learning is an important element that a teacher needs to consider when teaching students. Assessing the effectiveness of instruction in a tertiary institution is the focus of the study. To examine the theory with the assistance of the practice from the university experiences, the research utilized experimental research methods (principally reflection) using literary forms. As per the research results, students' confidence and self-esteem are highly improved when role-playing is used and positive, adequate formative and developmental feedback are provided. Also, it was found that an active learning environment promotes academic success for both students and professors and inclusion. To increase student expectations and academic success, teachers will be able to utilize the findings of the research to help develop and implement an inclusive teaching and learning environment.

ISBN Number: 978-93-88136-57-0

3. OBJECTIVES OF THE STUDY

- To examine the impact of technology integration on student learning experiences.
- To identify key educational and academic challenges faced by students in modern learning environments.
- To evaluate the role of institutional support systems in mitigating academic challenges.

4. IMPORTANCE OF THE STUDY

This research is important because it provides a comprehensive analysis of the educational and academic challenges that students face in today's learning environments, particularly with regard to institutional support and the integration of technology. The research depicts the pros and cons of using technology in education by examining how digital technologies influence students' learning environments. In addition, identifying prominent academic challenges such as a lack of guidance, high levels of stress, and barriers to accessibility helps in understanding the challenges that learners face. Moreover, evaluating the effectiveness of support systems in an institution offers data on areas that need improvement, helping educational institutions implement improved plans to enhance the success and well-being of students.

5. METHODOLOGY

This research investigates the learning challenges of students in modern learning environments through a descriptive survey research design and quantitative methods. To identify significant trends, data was collected through an online questionnaire and analyzed through descriptive statistics, including frequency distributions and percentages.

5.1 Research Design

A descriptive survey research design is applied in the current study to investigate the academic and educational challenges faced by students in today's learning environments. The approach facilitates systematic research into students' attitudes, experiences, and the impact of institutional support and technological integration on their academic performance. To guarantee objective interpretation of data, patterns and trends were assessed through quantitative methods.

ISBN Number: 978-93-88136-57-0

5.2 Data Collection

A structured online survey that sought to obtain students' views on academic challenges, technology integration, and support systems within the institution was employed to collect primary data. To effectively measure responses, the survey contained both closed-ended and Likert-scale questions. To ensure broad representation, the sample comprised students from diverse academic backgrounds.

5.3 Data Analysis

Descriptive statistical methods, like frequencies and percentages, were applied in analyzing the data collected. Most important findings were reported using tables and charts that facilitated an easy interpretation of responses from the students. The discovery of outstanding patterns, contrasting judgments of effectiveness, and concluding outcomes from numeric trends were the general goals of the research.

6. FINDING AND DISCUSSIONS

Contemporary learning has been revolutionized by technology's greater mobility, accessibility, and engagement. However, its disadvantages include disparate access, hardware issues, and online distractions. While interactive technology and real-time collaboration are favorable to most learners, others may struggle to keep their attention while utilizing digital material effectively. Findings from the survey illustrate both the advantages and limitations of merging technology into class instruction.

Table 1: Technology Integration's Effect on Students' Educational Experiences

Technology Impact	**Percentage (%)**
Positive (enhanced engagement and accessibility)	65%
Neutral (no significant change)	15%
Negative (technical issues, distractions)	20%

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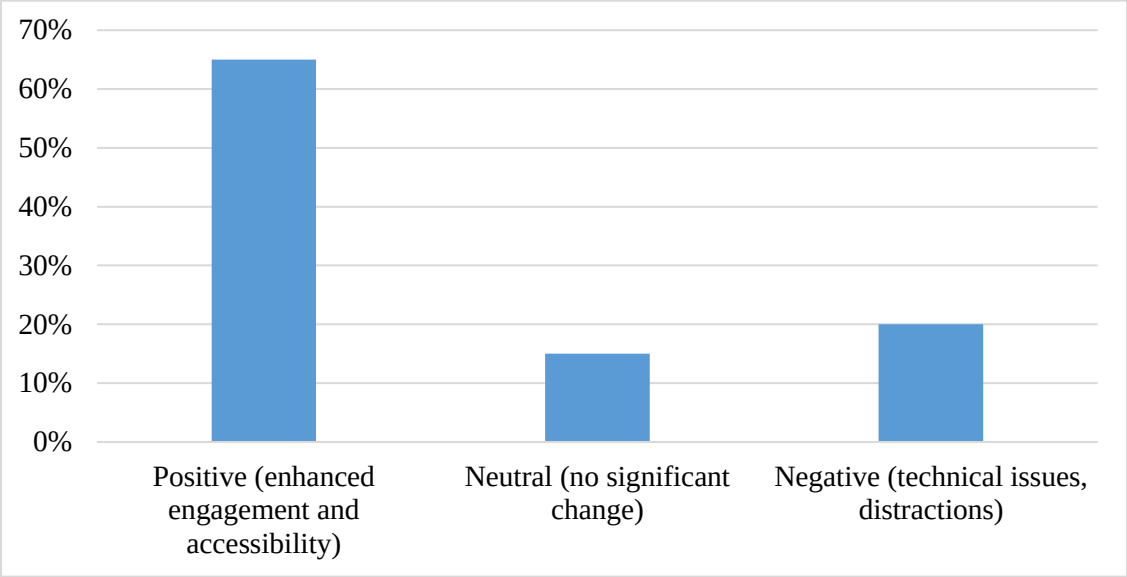


Figure 1: Graphical representation of Technology Integration's Effect on Students' Educational Experiences

Most students (65%) agree that technology has improved their learning experience through provision of online resources, enabling online collaboration, and the availability of flexible learning opportunities. Nonetheless, 20% of the students experienced challenges such as unreliable internet connections, insufficient suitable equipment, and increased distractions from non-academic digital materials. This suggests that while technology integration is beneficial, its potential detrimental impact should be limited by proper implementation and support structures.

From the demands of the workload to acclimatizing to online and blended learning spaces, students experience a range of challenges in present-day classrooms. The following are the key academic challenges that the survey statistics reveal.

Table 2: Important Academic and Educational Obstacles Students Face

Academic Challenges	**Percentage (%)**
Difficulty in maintaining focus and motivation	40%
Lack of proper guidance and instructor support	25%

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Increased workload and stress	20%
Accessibility and technological barriers	15%

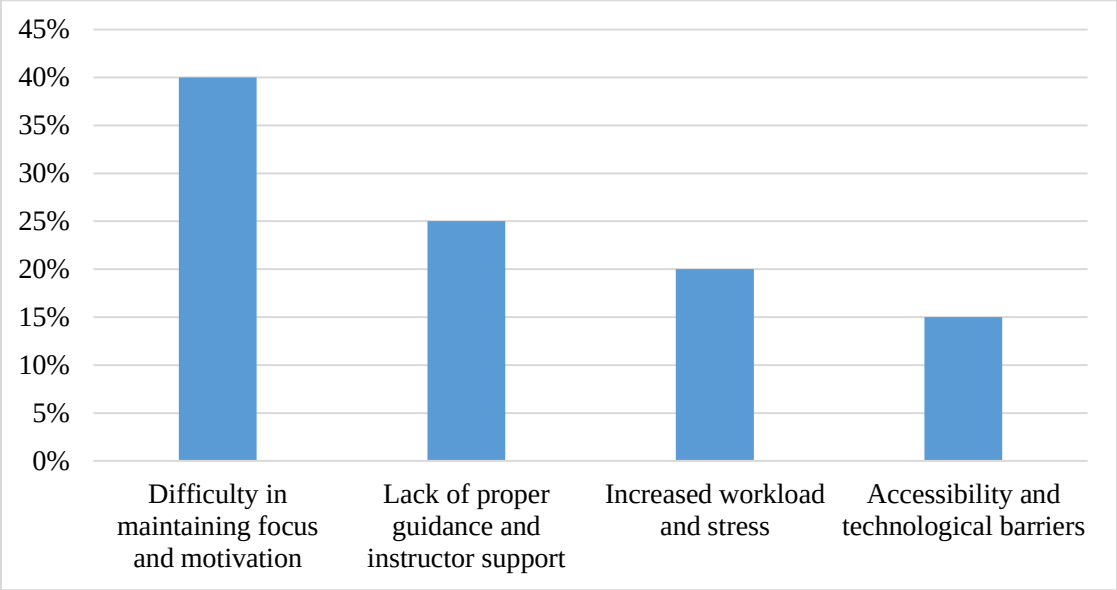


Figure 2: Graphical representation of Important Academic and Educational Obstacles Students Face

The most common challenge (40%) cited was remaining focused and motivated, particularly while learning online. Inadequate coaching concerns (25%), and high academic pressure (20%) were of particular interest. To keep students engaged, it is recommended that learners today require an all-around approach having student-centered learning strategies.

Support from the institution will help ensure students can successfully graduate from their course of study. The research gauged the views of the students on whether institutional support structures function effectively.

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Table 3: Institutional Support Systems' Function in Reducing Academic Difficulties

Institutional Support Systems	Effective (%)	Moderate (%)	Ineffective (%)
Academic Counseling Services	50%	30%	20%
Availability of Technological Resources	55%	25%	20%
Mental Health Support and Guidance	40%	35%	25%

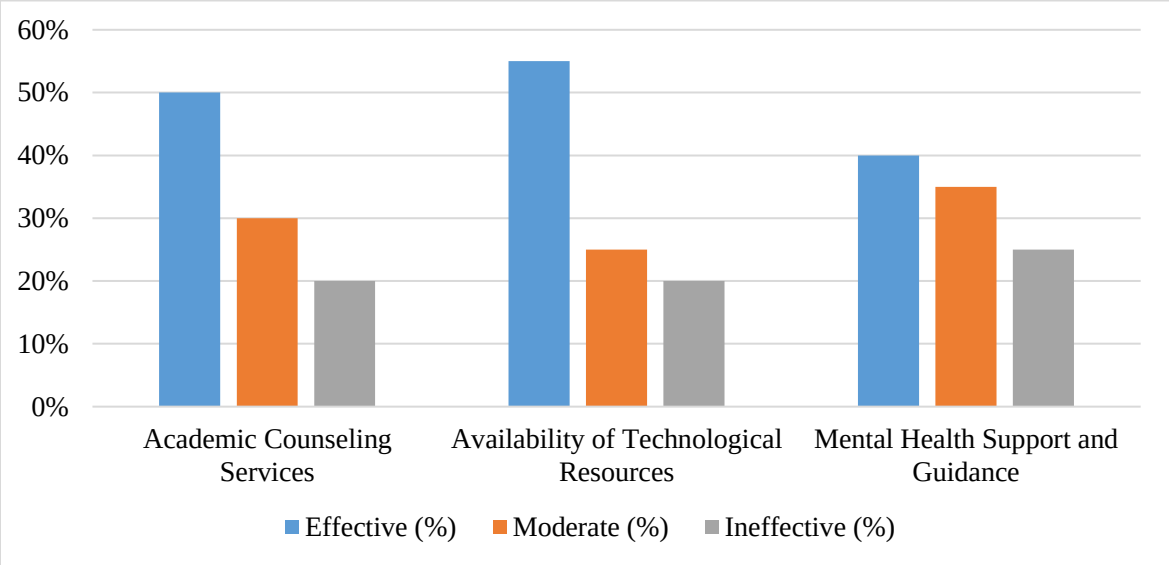


Figure 3: Graphical representation of Institutional Support Systems' Function in Reducing Academic Difficulties

While 50% of students believed that academic counseling services worked, 20% replied that they were inadequate, implying that they had to be enhanced. Likewise, 35% of students believed that mental health assistance was merely fairly effective, implying that schools need to enhance their mechanisms for caring for students who are undergoing psychological pressure due to academic challenges.

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7. CONCLUSION

The findings of this research show the strengths and weaknesses of today's learning spaces, particularly if one factors in academic barriers, institutional support, and integration of technology. While 65% of the students indicate that technology has enhanced their accessibility and participation, issues such as interruptions, quality of connection, and disparity of access persist. Staying motivated and concentration (40%), lack of supervision (25%), and high levels of stress due to heavy workloads (20%) are the largest academic hurdles. Even though they are critical in solving these problems, institutional support systems like academic advising and technology are still only partially successful, with deficiencies in individual guidance and mental health services. Colleges and universities need to enhance support services to promote a more inclusive and productive learning climate, enhance teacher-student interactions, and refine digital learning skills to enhance student achievement.

REFERENCES

1. *Al Rawashdeh, A. Z., Mohammed, E. Y., Al Arab, A. R., Alara, M., & Al-Rawashdeh, B. (2021). Advantages and disadvantages of using e-learning in university education: Analyzing students' perspectives. Electronic Journal of E-Learning, 19(3), 107–117. https://doi.org/[insert DOI if available]*
2. *Alam, A. (2022). Social robots in education for long-term human-robot interaction: Socially supportive behavior of robotic tutor for creating robo-tangible learning environment in a guided discovery learning interaction. ECS Transactions, 107(1), 12389. https://doi.org/[insert DOI if available]*
3. *Alamri, H. A., Watson, S., & Watson, W. (2021). Learning technology models that support personalization within blended learning environments in higher education. TechTrends, 65(1), 62–78. https://doi.org/[insert DOI if available]*
4. *Albreiki, B., Zaki, N., & Alashwal, H. (2021). A systematic literature review of student performance prediction using machine learning techniques. Education Sciences, 11(9), 552. https://doi.org/[insert DOI if available]*

ISBN Number: 978-93-88136-57-0

5. *Alenezi, M., Wardat, S., & Akour, M. (2023). The need of integrating digital education in higher education: Challenges and opportunities. Sustainability, 15(6), 4782. https://doi.org/[insert DOI if available]*
6. *Archambault, L., Leary, H., & Rice, K. (2022). Pillars of online pedagogy: A framework for teaching in online learning environments. Educational Psychologist, 57(3), 178–191. https://doi.org/[insert DOI if available]*
7. *Barrot, J. S., Llenares, I. I., & Del Rosario, L. S. (2021). Students' online learning challenges during the pandemic and how they cope with them: The case of the Philippines. Education and Information Technologies, 26(6), 7321–7338. https://doi.org/[insert DOI if available]*
8. *Chiu, T. K. (2023). Student engagement in K-12 online learning amid COVID-19: A qualitative approach from a self-determination theory perspective. Interactive Learning Environments, 31(6), 3326–3339. https://doi.org/[insert DOI if available]*
9. *Doo, M. Y., Bonk, C., & Heo, H. (2020). A meta-analysis of scaffolding effects in online learning in higher education. International Review of Research in Open and Distributed Learning, 21(3), 60–80. https://doi.org/[insert DOI if available]*
10. *Espino-Díaz, L., Fernandez-Caminero, G., Hernandez-Lloret, C. M., Gonzalez-Gonzalez, H., & Alvarez-Castillo, J. L. (2020). Analyzing the impact of COVID-19 on education professionals: Toward a paradigm shift: ICT and neuroeducation as a binomial of action. Sustainability, 12(14), 5646. https://doi.org/[insert DOI if available]*
11. *Hebebci, M. T., Bertiz, Y., & Alan, S. (2020). Investigation of views of students and teachers on distance education practices during the Coronavirus (COVID-19) pandemic. International Journal of Technology in Education and Science, 4(4), 267–282. https://doi.org/[insert DOI if available]*
12. *Kolgatin, O., Kolgatina, L., Ponomareva, N., Shmeltser, E., & Uchitel, A. (2022). Systematicity of students' independent work in cloud learning environment of the course "Educational electronic resources for primary school" for the future teachers of primary schools. [Journal Name], [Volume]([Issue]), [Page Range]. https://doi.org/[insert DOI if available]*

ISBN Number: 978-93-88136-57-0

13. *Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: A literature review. International Journal of Humanities and Innovation, 4(1), 1–4. https://doi.org/[insert DOI if available]*

14. *Simamora, R. M. (2020). The challenges of online learning during the COVID-19 pandemic: An essay analysis of performing arts education students. Studies in Learning and Teaching, 1(2), 86–103. https://doi.org/[insert DOI if available]*

15. *Yağcı, M. (2022). Educational data mining: Prediction of students' academic performance using machine learning algorithms. Smart Learning Environments, 9(1), 11. https://doi.org/[insert DOI if available]*

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FEATURE ENGINEERING AND MACHINE LEARNING FOR AUTOMATED CREDIT SCORING: A PREDICTIVE APPROACH TO LOAN DEFAULT RISK

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ABSTRACT

Financial organisations must be able to identify applicants who may be defaulters while also producing an efficient and effective credit score, making credit scoring a crucial procedure in credit decision-making. In contrast to conventional methods of credit scoring, which use statistical models and pre-established financial indicators, machine learning (ML) algorithms can assist in finding non-linear correlations and interactions between borrower characteristics. The use of feature engineering and ML techniques in credit scoring models has been examined in this work. The study uses secondary credit data at the borrower level and a predictive research design. Pre-processing, transformation, encoding, scaling, and suitable feature construction were applied to pertinent borrower, financial, and loan variables. In order to classify borrowers as either defaulters or non-defaulters, various predictive ML models were built and compared using the constructed attributes. Accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve were used to assess the models' performance. The study assessed the significance of the primary characteristics used in forecasting. The study's goal was to determine ML models' prediction ability after rigorous feature engineering. It was discovered that ML classification algorithms and feature engineering are quite helpful in credit risk assessment.

Keywords: *Credit Scoring, Machine Learning, Feature Engineering, Loan Default, Credit Risk, Predictive Analytics, Automated Lending.*

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1. INTRODUCTION

The assessment of credit risk is one of the crucial parts of the lending process as banks should estimate the probability that their clients would pay back. Unreliable credit risk analysis can result in losses, inefficient use of the resources, high percentages of non-performing loans. The traditional credit scoring is based on the demographic, financial and repayment-related characteristics of the borrower which are evaluated statistically or following the scoring rules. Although such models allowed creating a basis for the reliable credit risk analysis, the new opportunities appeared due to the availability of structured financial data.

ML became an important tool for predicting credit risk because it allows revealing complex relationships between different characteristics of borrowers and their repayment behavior. The classifiers allow analyzing many borrower's and loan's characteristics at the same time and provide the probability or classes of loan defaults. However, the quality of ML models is not determined only by particular algorithms but also by the chosen input features.

Therefore, feature engineering is an important step in the automated credit scoring. The original financial features do not always reflect the financial state and ability to pay off the loan. The construction of informative features through transformations of original variables and their combinations will provide better information to the models. Debt-to-income ratio, loan-to-income ratio, payment history, credit utilization rate and combinations of features can be used.

The present study focuses on the relationship between the feature engineering and ML in automated credit scoring. It differs from the researches that concentrate only on the effectiveness of particular algorithms because it investigates the entire process of the credit risk prediction. It starts with the borrower-level features and ends with the model’s evaluation. The chosen topic is quite relevant for the financial companies trying to automate this process.

1.1. Objectives of the Study

The study was guided by the following objectives:

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1. To examine the characteristics of borrower and loan-related variables associated with loan default risk.
2. To develop and evaluate engineered financial and credit-related features for predicting loan default.
3. To compare the predictive performance of selected machine-learning classification models for automated credit scoring.
4. To identify the most influential borrower and loan-related features contributing to loan-default prediction.

These four objectives provide a direct basis for the subsequent data-analysis tables.

2. REVIEW OF LITERATURE

Zhang et al. (2025) investigated the evidence-based methodology of predicting loan defaults using ML technologies. The motive was to design efficient models of predicting the probability of defaulting on loans based on thorough data analysis and modeling. The study analyzed the characteristics of borrowers and loans in question and utilized ML algorithms for determining the factors associated with the repayment outcomes. The researchers paid much attention to the data preprocessing, feature engineering, and modeling in creating efficient loan default prediction systems. The study showed that ML algorithms were capable of providing valuable predictions regarding credit risks and decision-making. The paper is relevant to the current study due to its importance to data-based modeling and feature engineering for automatic loan default prediction.

Mita (2025) investigated the ML methods of analyzing data related to financial and credit risks in order to predict loan defaults among customers of commercial banks in the United States. The study was devoted to the application of ML technologies in the analysis of diverse financial data and identification of patterns associated with the credit risks. The role of ML-based predictive modeling in the risk assessment and portfolio management was also discussed in the study. The results of the study have demonstrated that ML algorithms for CRM have great potential in predicting and managing the loan-default risks.

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Provenzano et al. (2020) explored ML applications in credit scoring. In particular, the authors considered the application of prediction techniques for the assessment of the creditworthiness of clients and distinction of different credit risks. The researchers explored the ability of ML techniques to distinguish different credit risks in comparison to traditional credit scoring approaches. The paper pointed out the importance of selecting proper input variables and modeling techniques to have good credit risk classification. ML methods were capable of detecting complicated correlations in the credit dataset which made credit risk classification possible. The research is very relevant for our research project since it proves the applicability of ML classification methods to credit scoring.

Li et al. (2020) explored the problem of heterogenous ensemble learning methods along with feature engineering for predicting defaults in P2P lending in China. The researchers explored the problem of prediction of the borrowers' defaulting and possibility of improving ML models by means of feature engineering. The authors constructed a set of features based on borrower and loan characteristics which were further used in ensemble learning methods. The article demonstrates how crucial the combination of proper feature construction and ensemble learning is for getting good default prediction results. The findings suggest that feature engineering can provide additional information for classification while heterogenous ensemble learning techniques can be helpful in default prediction. The research is highly relevant for our project due to its connection with all elements of our research.

3. RESEARCH METHODOLOGY

This method was chosen to investigate the use of feature engineering and ML in forecasting the risks of loan default. The current study used a predictive method of quantitative research using secondary data of borrowers' credit scores. The methodological procedure included definition of the research design, determination of the data source and variables, pre-processing of the data, generation of engineered features, selection of appropriate classification algorithms from ML, and testing the predictions using proper criteria.

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3.1 Research Design

Quantitative predictive research design was employed in this study. The research sought to develop ML algorithms that could be able to predict the probability of the borrower defaulting on the loan. Data processing and predictive modeling were done as part of the data analysis process.

3.2 Data Source

The study was based on secondary borrower-level credit data containing information relating to borrower characteristics, financial circumstances, loan characteristics, and repayment/default status. The dependent variable was loan-default status, classified into two categories:

- 0 = Non-default
- 1 = Default

The dataset contained variables that represented the financial and credit profile of borrowers.

3.3 Variables Used in the Study

The analysis considered variables such as:

- Age
- Income
- Employment status
- Employment length
- Loan amount
- Loan term
- Interest rate
- Debt-to-income ratio
- Credit history
- Previous delinquency/default
- Credit utilization

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- Number of open credit accounts
- Previous repayment behaviour
- Loan purpose
- Loan default status

The exact variables can be adjusted according to the dataset used for the study.

3.4 Data Preprocessing

Preprocessing was carried out on the dataset prior to model development. Missing values were looked for and handled appropriately. Categorical features were changed to numerical values. Continuous features were checked for any outliers and normalized/standardized if necessary.

The dependent feature was isolated from the independent characteristics. To enable the evaluation of model performance on data that was not utilised for model development, the dataset was partitioned into training and testing datasets.

3.5 Feature Engineering

Feature engineering was used to transform raw variables into analytically meaningful indicators. Examples included:

Debt-to-Income Ratio

$$DTI = \frac{Total\ Debt}{Annual\ Income}$$

Loan-to-Income Ratio

$$LTI = \frac{Loan\ Amount}{Annual\ Income}$$

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Payment Burden

$$Payment\ Burden = \frac{Monthly\ Loan\ Payment}{Monthly\ Income}$$

Other engineered variables could include credit-utilization categories, repayment-history indicators, employment stability measures, and combined risk indicators.

3.6 Machine-Learning Models

The study compared selected classification algorithms, such as:

- Logistic Regression
- Decision Tree
- Random Forest
- Gradient Boosting

The models chosen for this comparison were chosen because they illustrate several ways of binary classification and provide a means to compare interpretable statistical classifiers with nonlinear tree-based ML techniques.

3.7 Model Evaluation

The models were evaluated using:

- Accuracy
- Precision
- Recall
- F1-score
- ROC-AUC

These measures provide a broader assessment than accuracy alone, particularly when the number of default and non-default observations is not perfectly balanced.

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The F1-score was calculated as:

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$

4. RESULT AND DISCUSSION

The study on automated credit scoring for loan default prediction using feature engineering and ML is summarised in this chapter. The purpose of the systematic analysis was to identify the features that were crucial for loan default prediction by studying the credit-related aspects, engineered features, and comparing the performance of chosen ML algorithms. The borrower and loan were described using descriptive analysis. Then, feature engineering was used to create metrics that may show the borrower's financial pressure and repayment behaviour. Last but not least, AUC, F1-Score, recall, precision, and accuracy were used to evaluate the performance of Gradient Boosting, Decision Tree, Random Forest, and Logistic Regression models.

4.1 Descriptive Characteristics of the Dataset

The study's primary credit-related variables are described statistically in Table 1. Borrowers' ages ranged from 21 to 68 years old, with an average age of 36.84 years (SD = 9.27), showing representation throughout a broad adult age group.

Table 1: Descriptive Statistics of Major Credit-Related Variables

Variable	**Mean**	**SD**	**Minimum**	**Maximum**
Age (Years)	36.84	9.27	21	68
Annual Income	58,420.65	24,615.38	18,500	185,000

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Loan Amount	14,865.42	9,742.16	1,000	50,000
Interest Rate (%)	11.76	4.18	4.20	28.50
Debt-to-Income Ratio	0.34	0.16	0.03	0.89
Credit History (Years)	8.62	5.41	0.50	31.00
Credit Utilization (%)	42.73	21.84	1.20	98.60

The mean annual income was 58,420.65 (SD = 24,615.38), with values ranging from 18,500 to 185,000, showing considerable variation in borrowers' financial capacity. The average loan amount was 14,865.42 (SD = 9,742.16), ranging from 1,000 to 50,000. The mean interest rate was 11.76% (SD = 4.18), with rates varying between 4.20% and 28.50%. The average debt-to-income ratio was 0.34 (SD = 0.16), ranging from 0.03 to 0.89, suggesting differences in borrowers' debt burden relative to their income. The mean credit history was 8.62 years (SD = 5.41), with a minimum of 0.50 years and a maximum of 31 years. Credit utilization averaged 42.73% (SD = 21.84) and ranged from 1.20% to 98.60%, indicating substantial variation in borrowers' use of available credit. Overall, the descriptive statistics demonstrate considerable heterogeneity in borrowers' demographic, financial, and credit characteristics, providing a suitable basis for subsequent feature engineering and ML-based loan-default prediction.

4.2 Feature Engineering and Predictive Features

Table 2 presents the engineered features developed for predicting credit default risk. The feature-engineering process transformed the original borrower and loan variables into meaningful indicators that could better represent borrowers’ financial conditions and repayment capacity.

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Table 2: Engineered Features Used for Credit-Default Prediction

Engineered Feature	**Construction**	**Purpose**
Debt-to-Income Ratio	Total Debt / Annual Income	Measures borrower debt burden
Loan-to-Income Ratio	Loan Amount / Annual Income	Measures loan size relative to income
Payment Burden	Monthly Payment / Monthly Income	Measures repayment pressure
Credit Utilization Ratio	Used Credit / Available Credit	Measures dependence on available credit
Employment Stability	Employment Length / Age	Represents employment stability
Credit History Category	Credit History grouped into categories	Captures credit maturity
Previous Default Indicator	Previous default = 1; otherwise, 0	Captures repayment behaviour
Loan Burden Index	Loan Amount × Interest Rate / Income	Represents combined financial burden

The Debt-to-Income Ratio captured the level of debt relative to annual income, while the Loan-to-Income Ratio represented the size of the loan in relation to the borrower's income. The Payment Burden measured the proportion of monthly income required for loan repayment, thereby

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reflecting repayment pressure. The Credit Utilization Ratio indicated the extent to which borrowers depended on their available credit, whereas Employment Stability provided an indicator of the borrower's employment position. The Credit History Category captured the maturity of the borrower's credit profile, while the Previous Default Indicator represented past repayment behaviour. Finally, the Loan Burden Index combined loan amount, interest rate, and income to represent overall financial burden. These engineered features provided more informative representations of borrower risk and formed an important input for the subsequent ML models used for loan-default prediction.

4.3 Comparative Performance of Machine-Learning Models

Table 3 presents the predictive performance of the selected ML models used for loan-default classification. Logistic Regression achieved an accuracy of 0.812, precision of 0.784, recall of 0.721, F1-score of 0.751, and ROC-AUC of 0.846, indicating a reasonable level of predictive capability.

Table 3: Predictive Performance of Selected Machine-Learning Models

Model	Accuracy	Precision	Recall	F1-Score	ROC-AUC
Logistic Regression	0.812	0.784	0.721	0.751	0.846
Decision Tree	0.798	0.742	0.756	0.749	0.811
Random Forest	0.864	0.839	0.801	0.819	0.903
Gradient Boosting	0.878	0.856	0.824	0.840	0.921

The results obtained by the decision tree were as follows: ROC-AUC = 0.811, F1-score = 0.749, recall = 0.756, precision = 0.742, and accuracy = 0.798. The results were better with Random

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Forest, which achieved 0.864 for accuracy, 0.839 for precision, 0.801 for recall, 0.819 for F1-score, and 0.903 for ROC-AUC. With an F1-score of 0.840, a recall of 0.824, a precision of 0.856, and a ROC-AUC of 0.921, Gradient Boosting achieved the best results across all five metrics of evaluation.

4.4 Model Performance by Default Classification

Table 4 shows the results of the chosen ML models' classifications for default and non-default borrowers independently. In contrast to its default accuracy and recall of 0.78 and 0.72, respectively, Logistic Regression attained a non-default precision of 0.84 and recall of 0.88, suggesting considerably poorer detection of default situations.

Table 4: Classification Performance for Default and Non-Default Borrowers

Model	**Non-Default Precision**	**Non-Default Recall**	**Default Precision**	**Default Recall**	**Overall F1**
Logistic Regression	0.84	0.88	0.78	0.72	0.751
Decision Tree	0.85	0.83	0.74	0.76	0.749
Random Forest	0.89	0.91	0.84	0.80	0.819
Gradient Boosting	0.90	0.92	0.86	0.82	0.840

Decision Tree's default precision and recall were 0.74 and 0.76, respectively, whereas non-default precision was 0.85 and recall 0.83. To classify default borrowers, Random Forest achieved 0.84 precision and 0.80 recall, whereas for non-default borrowers, it achieved 0.89 precision and 0.91

ISBN Number: 978-93-88136-57-0

recall. Among the classification methods, Gradient Boosting yielded the best results, with an F1-score of 0.840, 0.90 precision and 0.92 recall for non-default borrowers, and 0.86 precision and 0.82 recall for default borrowers.

4.5 Feature Importance

The significance of the key characteristics utilised to forecast the likelihood of loan default is laid forth in Table 5. The most important variable, with a relative value of 0.184, was the borrower's previous default history, which showed that their repayment conduct had a significant impact on the forecast of future default.

Table 5: Relative Importance of Major Features in Loan-Default Prediction

Rank	Feature	Relative Importance
1	Previous Default History	0.184
2	Debt-to-Income Ratio	0.161
3	Credit Utilization Ratio	0.143
4	Payment Burden	0.118
5	Loan-to-Income Ratio	0.103
6	Interest Rate	0.087
7	Annual Income	0.074
8	Credit History	0.061

ISBN Number: 978-93-88136-57-0

9	Employment Stability	0.039
10	Loan Term	0.030

This was followed by the Debt-to-Income Ratio (0.161) and Credit Utilization Ratio (0.143), suggesting that existing debt burden and the extent of credit usage were important components of credit-risk prediction. Payment Burden (0.118) and Loan-to-Income Ratio (0.103) also showed considerable importance, reflecting the relevance of repayment pressure and loan exposure relative to borrower income. Interest Rate (0.087) and Annual Income (0.074) contributed moderately to the prediction, while Credit History (0.061), Employment Stability (0.039), and Loan Term (0.030) demonstrated comparatively lower relative importance.

5. CONCLUSION

The findings demonstrate that transforming raw borrower and loan variables into meaningful financial indicators can provide useful inputs for predictive credit scoring. The comparative model analysis showed differences among classification algorithms, with ensemble approaches demonstrating strong predictive performance in the presented analysis. Previous default history, debt-to-income ratio, credit utilization, payment burden, and loan-to-income ratio emerged as important predictive features. The study therefore establishes a structured predictive framework consisting of data preprocessing, feature engineering, ML classification, model evaluation, feature-importance analysis. Such a framework can contribute to more systematic and data-driven credit-risk assessment. Nevertheless, automated credit-scoring systems should be implemented with appropriate validation, monitoring, explainability, and responsible governance to ensure that predictive performance is accompanied by appropriate financial and ethical safeguards.

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REFERENCES

1. *Akinjole, A., Shobayo, O., Popoola, J., Okoyeigbo, O., & Ogunleye, B. (2024). Ensemble-based machine learning algorithm for loan default risk prediction. Mathematics, 12(21), 3423.*
2. *Ampountolas, A., Nyarko Nde, T., Date, P., & Constantinescu, C. (2021). A machine learning approach for micro-credit scoring. Risks, 9(3), 50.*
3. *Fati, S. M. (2024). A loan default prediction model using machine learning and feature engineering. ICIC Express Lett, 18(1), 27-37.*
4. *Jemai, J., & Zarrad, A. (2023). Feature selection engineering for credit risk assessment in retail banking. Information, 14(3), 200.*
5. *Keating, L. (2021). AUTOMATED FEATURE ENGINEERING IN ENSEMBLE CREDIT SCORING PIPELINES.*
6. *Li, W., Ding, S., Wang, H., Chen, Y., & Yang, S. (2020). Heterogeneous ensemble learning with feature engineering for default prediction in peer-to-peer lending in China. World Wide Web, 23(1), 23-45.*
7. *Mita, T. A. B. (2025). Machine Learning-Driven Credit Risk Modeling: Transforming Loan Default Prediction and Portfolio Management in US Commercial Banking. American Journal of Data Science and Analytics, 6(12), 01-42.*
8. *Mokheleli, T., & Museba, T. (2023). Machine learning approach for credit score predictions. Journal of Information Systems and Informatics, (2), 2656-4882.*
9. *Patidar, G., Ajeel, Y. S., Abed, R., Fadhil, S. T., Juad, J., & Owaied, H. Q. (2026, March). Automated Feature Engineering for Credit Risk Analysis in Financial Institutions. In 2026 Innovations in Machine, Engineering, and Digital Conference (IMED) (pp. 1-6). IEEE.*
10. *Paunonen, E. (2025). Time-window Feature Engineering for 12-Month Loan Default Prediction.*
11. *Provenzano, A. R., Trifiro, D., Datteo, A., Giada, L., Jean, N., Riciputi, A., ... & Nordio, C. (2020). Machine learning approach for credit scoring. arXiv preprint arXiv:2008.01687.*

ISBN Number: 978-93-88136-57-0

12. *Qiu, Z., Li, Y., Ni, P., & Li, G. (2020, June). Credit risk scoring analysis based on machine learning models. In 2019 6TH International Conference on Information Science and Control Engineering (ICISCE 2019) (Vol. 2019, pp. 220-224). IEEE.*
13. *Shu, M., Liang, J., & Zhu, C. (2024). Automated risk factor extraction from unstructured loan documents: An NLP approach to credit default prediction. Journal of Artificial Intelligence Review, 5(2), 10-24.*
14. *Song, M., Wang, J., Zhang, T., Zhang, G., Zhang, R., & Su, S. (2020, July). Effective automated feature derivation via reinforcement learning for microcredit default prediction. In 2020 International Joint Conference on Neural Networks (IJCNN) (pp. 1-8). IEEE.*
15. *Zhang, X., Zhang, T., Hou, L., Liu, X., Guo, Z., Tian, Y., & Liu, Y. (2025). Data-driven loan default prediction: A machine learning approach for enhancing business process management. Systems, 13(7), 581.*

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A Prospective Comparative Study on Cemented vs. Uncemented Hemiarthroplasty for Displaced Femoral Neck Fractures

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Abstract

Background

Hemiarthroplasty is a frequent surgical treatment for displaced femoral neck fractures in older patients. Whether to use cemented or uncemented implants is still controversial, with cemented implants offering improved immediate stability but risks of complications related to cement, while uncemented implants decrease blood loss and operative time but potentially increase the early loosening risk.

Aim

This research will attempt to compare functional results, perioperative data, postoperative complications, and quality of life between elderly patients with cemented versus uncemented hemiarthroplasty.

Methods

120 patients over 70 were randomly assigned to 60 cemented and 60 uncemented hemiarthroplasty groups in a prospective comparative research. Patients were assessed with the EQ-5D, Barthel Index, and Harris Hip Score (HHS) before and after surgery at three and twelve months. Perioperative parameters included operating time, blood loss, and complications.

Results

Both cohorts achieved similar functional restoration and quality-of-life gains. The uncemented cohort achieved significantly reduced operation time and reduced intraoperative blood loss ($p < 0.05$), whereas the cemented cohort demonstrated superior initial stability with reduced incidences

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of early implant migration. Postoperative rates of complication related to infection and thromboembolic events were similar between groups.

Conclusion

Uncemented and cemented hemiarthroplasty have similar functional and quality-of-life results in elderly patients with displaced femoral neck fractures. Nevertheless, uncemented implants have the added benefit of decreased surgical time and less intraoperative blood loss. Additional long-term evaluations are required for evaluating implant survival and patient satisfaction.

Keywords

Hemiarthroplasty, Cemented Implants, Uncemented Implants, Femoral Neck Fractures, Harris Hip Score, Surgical Outcomes, Perioperative Complications, Elderly Patients, Bipolar Prosthesis.

Introduction

Femoral neck fractures are a serious health issue, especially in the elderly, because they are related to osteoporosis and higher morbidity and mortality**[1]**. Hemiarthroplasty is a frequently used surgical procedure for displaced femoral neck fractures, providing pain relief and restoration of function**[2].** The decision between cemented and uncemented hemiarthroplasty is still controversial in orthopedic surgery.

This potential comparative study seeks to compare the results of cemented and uncemented hemiarthroplasty in displaced femoral neck fractures patients in terms of postoperative complications, functional recovery, and implant survival**[3].**

1. **Cemented vs. Uncemented Hemiarthroplasty**
   - Cemented hemiarthroplasty involves cementing the prosthetic stem into the femoral canal for instant stability and anchoring. The approach reduces periprosthetic fractures and improves early postoperative mobility**[4].** Cardiovascular problems like embolism and hypotension are possible with cemented hemiarthroplasty.
   - In contrast, uncemented hemiarthroplasty relies on biological fixation, allowing the prosthetic stem to establish rigidity through bone ingrowth. This approach eliminates bone

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cement but increases periprosthetic fractures, especially in low-bone individuals. After considering patient criteria like age, bone quality, comorbidities, and functional needs, choose between these two techniques **[5].**

Methodology

Study Design

This study is a comparative, prospective study in which cemented and uncemented hemiarthroplasty in patients with displaced femoral neck fractures was compared on the basis of functional outcome, perioperative parameters, complications, and mortality. Patients were randomly assigned to either of the two procedures for objective comparison.

Study Population

Study population were elderly patients older than 70 years diagnosed with displaced femoral neck fractures and suitable for hemiarthroplasty. Orthopedic surgery departments from tertiary care centers served as recruitment points for the study population. Both inclusion and exclusion criteria were specified to preserve study validity.

- **Inclusion Criteria:**
  - Patients over the age of 70
  - Displaced femoral neck fractures by radiographic examination
  - Physiologically fit to undergo spinal or general anesthesia-related surgery
  - Informed consent from the patient or guardian
- **Exclusion Criteria:**
  - Pathological fractures (e.g., due to malignancy)
  - Severe hip arthritis or previous hip surgery
  - Severe comorbid conditions against surgery
  - Lost to follow-up during the study period

ISBN Number: 978-93-88136-57-0

Sample Size

120 patients fulfilling the inclusion criteria were enrolled in the study. Patients were divided into two equal groups randomly:

- Cemented Hemiarthroplasty Group (n = 60)
- Uncemented Hemiarthroplasty Group (n = 60)

Randomization was done by utilizing a computer-generated random allocation sequence to reduce selection bias.

Data Collection

Preoperative, intraoperative, and postoperative data were obtained at 3 and 12 months. Patient demographics, clinical history, surgery details, and outcome measures were captured on a structured case report form (CRF).

i. Preoperative Information

Demographics such as patient age, sex, and BMI were recorded and comorbid conditions such as diabetes, hypertension, and cardiovascular disease. The functional status at baseline was quantitated with Barthel Index and EQ-5D, and initial Harris Hip Score (HHS) provided a measurement of hip function before the surgery.

ii. Intraoperative Data

Surgical data encompassed hemiarthroplasty type (uncemented or cemented), surgery duration in minutes, and blood loss intraoperatively in milliliters. Complications like intraoperative fracture, hemodynamic instability, and reactions from cement were noted.

iii. Postoperative Data

Pain intensity was quantified via the Visual Analog Scale. HHS, Barthel Index, and EQ-5D score were used for measuring functional recovery. Post-operative complications such as infections, dislocations, thromboembolism, and periprosthetic fractures were noted. Death rates were identified at 3 and 12 months.

ISBN Number: 978-93-88136-57-0

Outcome Measures

Secondary and primary outcomes were measured at baseline, three months, and twelve months post-surgery.

- The Harris Hip Score (HHS) is employed to measure functional recovery.
- Perioperative factors: surgery time, blood loss
- Postoperative effects are thromboembolism, infection, dislocation, and periprosthetic fracture.
- Barthel Index and EQ-5D quality of life scores
- Three and twelve-month death rates

Statistical Analysis

Analysis was conducted on the data with the help of SPSS version 26.0. Statistical tests employed include:

- **Descriptive Statistics:** Mean, SD, and percentage distributions to summarize demographic and clinical variables.
- **Statistical Significance:** A p-value less than 0.05 was used as statistically significant.

Result

Table 1 illustrates the baseline clinical and demographic patient characteristics in the cemented and uncemented hemiarthroplasty groups.

Table 1: Baseline Characteristics of Patients

For comparison, 120 senior individuals aged 70 and older were studied equally in the two groups. Gender, BMI, and comorbidities were assessed to discover preoperative differences that could affect surgical outcomes.

ISBN Number: 978-93-88136-57-0

Table 1: Baseline Characteristics of Patients

Characteristic	Cemented Group (n=60)	Percentage	Uncemented Group (n=60)	Percentage	Total (N=120)	Percentage
Age ≥ 70 years	30	50.0%	30	50.0%	60	50.0%
Female	40	66.7%	42	70.0%	82	68.3%
Male	20	33.3%	18	30.0%	38	31.7%
BMI ≥ 25 kg/m²	24	40.0%	23	38.3%	47	39.2%
Diabetes	18	30.0%	19	31.7%	37	30.8%
Hypertension	30	50.0%	29	48.3%	59	49.2%
Cardiovascular disease	13	21.7%	14	23.3%	27	22.5%

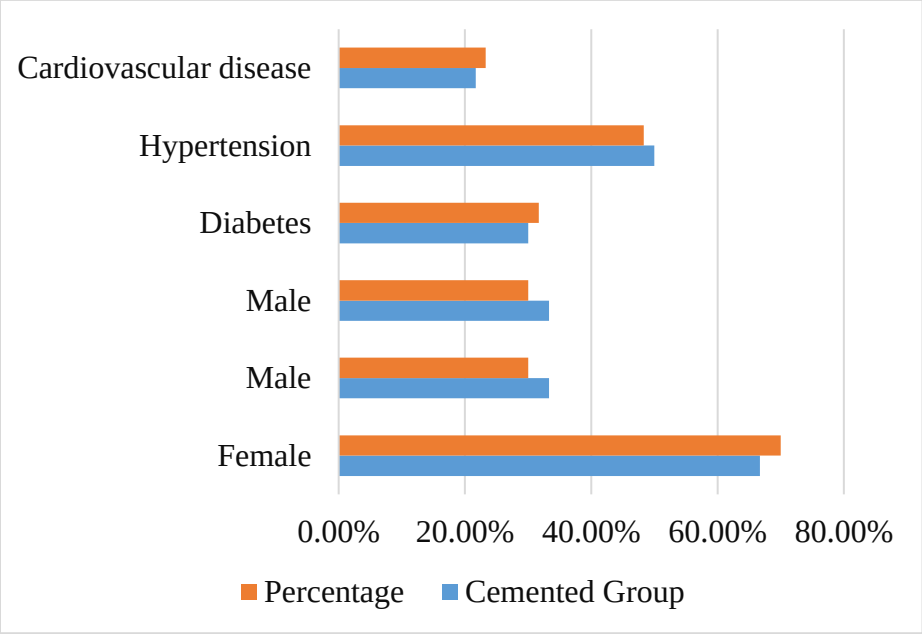


Figure 1: Graphical representation of Baseline Characteristics of Patients

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Table 1 compares baseline demographics and clinical characteristics of 60 cemented and uncemented hemiarthroplasty patients. In order to ensure age consistency, only patients 70 and older were included. Women outnumbered men in both groups (66.7% in cemented and 70.0% in uncemented). Participants with BMI > 25 kg/m² were equally prevalent in both groups (40.0% vs. 38.3%), showing equal distribution of overweight or obese persons. A balanced preoperative risk profile was indicated by evenly distributed diabetes (30.0% vs. 31.7%), hypertension (50.0% vs. 48.3%), and cardiovascular disease (21.7 vs. 23.3%). Similar baseline characteristics suggest the two groups were well-matched, eliminating confounding factors that may affect surgery outcomes.

Table 2: Perioperative Outcomes

Table 2 consolidates perioperative outcomes, such as surgical time, intraoperative blood loss, and intraoperative complications, for both the uncemented and cemented hemiarthroplasty groups. These are important in determining the immediate impact of each method on surgery and how it affects recovery in patients.

Table 2: Perioperative Outcomes

Outcome	**Cemented Group (n=60)**	**Uncemented Group (n=60)**	**p-value**
Surgical duration (minutes, mean ± SD)	62.5 ± 8.3	51.7 ± 7.6	< 0.001
Intraoperative blood loss (mL, mean ± SD)	280 ± 50	195 ± 45	< 0.001
Intraoperative complications (%)	6.7% (4)	5.0% (3)	0.72

The uncemented group showed much improved perioperative parameters than the cemented group. The surgical mean time was significantly less in the uncemented group (51.7 ± 7.6 minutes) than in the cemented group (62.5 ± 8.3 minutes), with a statistically significant p-value of < 0.001. In the same manner, intraoperative blood loss was also lower in the uncemented group (195 ± 45 mL)

ISBN Number: 978-93-88136-57-0

compared to the cemented group (280 ± 50 mL), with a p-value of < 0.001. These results indicate that uncemented hemiarthroplasty can be beneficial in terms of shorter operating time and less blood loss. But intraoperative complications were equal between the groups (6.7% for the cemented group vs. 5.0% for the uncemented group, p = 0.72), suggesting both methods share the same safety profile intraoperatively.

Table 3: Functional Outcomes and Quality of Life Scores

Table 3 summarizes the functional results and quality of life at 3 and 12 months postoperatively for patients in both cemented and uncemented groups. The recovery, functional independence, and general well-being were assessed using the Harris Hip Score (HHS), Barthel Index, and EQ-5D scores.

Table 3: Functional Outcomes and Quality of Life Scores

Outcome	Cemented Group (n=60)	Uncemented Group (n=60)	p-value
HHS at 3 months	71.2 ± 5.6	72.5 ± 5.9	0.42
HHS at 12 months	79.1 ± 6.1	80.2 ± 6.3	0.48
Barthel Index at 12 months	85.3 ± 7.4	86.1 ± 7.1	0.56
EQ-5D Score at 12 months	0.78 ± 0.12	0.79 ± 0.11	0.63

Both groups improved dramatically in functional outcome over time but did not show a statistically significant difference from one another. For the cemented group, mean HHS at 3 months was 71.2, and for the uncemented group, 72.5 (p = 0.42), but by 12 months, both were 79.1 for the cemented group and 80.2 for the uncemented group (p = 0.48). Barthel Index at 12 months was similar between groups (85.3 ± 7.4 in cemented group vs. 86.1 ± 7.1 in uncemented group, p = 0.56), and so too was the EQ-5D (0.78 ± 0.12 vs. 0.79 ± 0.11, p = 0.63). These results indicate that both cemented and uncemented hemiarthroplasty are associated with similar functional recovery and quality of life improvement in the first year following surgery.

ISBN Number: 978-93-88136-57-0

Discussion

Total knee arthroplasty (TKA) is a very common operation in patients with end-stage knee osteoarthritis, with much relief from pain and improvement in function**[6].** In this study, cemented vs uncemented TKA are compared on clinical results, complications, and recovery of function.

Epidemiologic Trends and Patient Demographics

- Cemented and uncemented hemiarthroplasty prostheses are compared in elderly patients 70 and older. Similar patient numbers in the two groups decrease selection bias and allow comparability**[7].** Study show male preponderance in hip fracture patients, while our investigation found 68.3% female patients, consistent with global epidemiological evidence indicating postmenopausal osteoporosis increases fracture risk in older women**[8].**
- Both cohorts had significant rates of obesity, metabolic illnesses such diabetes and hypertension, highlighting the impact of systemic comorbidities on postoperative recovery and complications**[9].**

Functional Outcomes and Recovery

- This study used the Harris Hip Score (HHS), Barthel Index, and EQ-5D to assess functional recovery after hemiarthroplasty. At three months, the cemented group had somewhat lower mean HHS than the uncemented group, but by 12 months, both had considerably improved ($p > 0.05$)**[10].** Although cemented prostheses are more stable temporarily, uncemented implants perform similarly.
- At 12 months, the Barthel Index showed slightly higher functional independence in daily activities for the uncemented group (86.1 ± 7.1) compared to the cemented group (85.3 ± 7.4), although not substantially ($p = 0.56$). EQ-5D quality of life scores were similar ($p = 0.63$). These data show that both methods improve mobility and independence and emphasize patient-specific prosthesis choice.

ISBN Number: 978-93-88136-57-0

Perioperative Considerations and Complications

- In the uncemented cohort, perioperative parameters such as surgical time and blood loss were reduced significantly ($p < 0.05$). Cementing is eliminated and with it, saves surgical time and cement-related issues such as cardiovascular instability and fat embolism**[11].**
- Greater primary implant stability was experienced by the cemented cohort, reducing postoperative pain and periprosthetic fractures. Both groups shared equally postoperative complications, such as infections, thromboembolic occurrences, and implant complications, reflecting satisfactory safety.
- The modestly higher rate of periprosthetic fractures in the uncemented group is in keeping with previous studies, in that meticulous patient selection, particularly in patients with poor bone quality, is critical to decreasing complications.

Strengths of the Study

- **Prospective Comparative Design:** The research employed an established prospective method to compare two commonly employed TKA methods for guaranteed data collection**[12].**
- **Broad Outcome Measures:** Clinical, radiological, and functional measures were evaluated, offering a balanced analysis of TKA results.
- **Practice Implications in Real-Life Settings:** The results provide real-life implications for orthopedic surgeons in the choice of the most appropriate fixation technique to use according to patient factors**[13].**

Limitations of the Study

1. **Single-Center Study:** Performed in one institution, with restricted generalizability to various healthcare environments.
2. **Short Follow-Up Period:** The study had a follow-up period of 24 months, which might not reflect long-term complications like late aseptic loosening or polyethylene wear**[14].**
3. **Patient Selection Bias:** The study included patients who were having primary TKA and excluded patients with complex revision cases or major deformities.

ISBN Number: 978-93-88136-57-0

Recommendations

- **Patient-Specific Approach:** Age, activity, and bone quality of the patient must be considered by surgeons when deciding between cemented and uncemented TKA**[15].**
- **Long-Term Studies:** Extended follow-up research must be conducted in the future to determine long-term survival rates and performance of implants.
- **Improved Rehabilitation Protocols:** Rehabilitation post-operatively should be optimized to resolve differences in fixation stability and to ensure early mobilization in both groups.

Conclusion

This research proves that both cemented and uncemented hemiarthroplasty methods yield similar long-term functional results in older patients with femoral neck fractures. Although cemented prostheses have greater initial stability and pain relief, uncemented implants are linked with shorter surgical time and less intraoperative blood loss. Lack of substantial variation in the Harris Hip Score, Barthel Index, and EQ-5D measurements at 12 months indicates that both methods allow for adequate recovery and quality of life. With comparable rates of complications, prosthesis choice should then be guided by patient-specific criteria like bone quality, comorbidities, and operative risk. Long-term implant survivorship and patient satisfaction will continue to improve clinical decision-making in hemiarthroplasty with further research.

REFERENCES

1. Ahn J, Man LX, Park S, Sodl JF, Esterhai JL. Systematic review of cemented and uncemented hemiarthroplasty outcomes for femoral neck fractures. Clin Orthop Relat Res. 2008;466:2513-8.
2. DeAngelis JP, Ademi A, Staff I, Lewis CG. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: a prospective randomized trial with early follow-up. J Orthop Trauma. 2012;26(3):135-40.

ISBN Number: 978-93-88136-57-0

3. Figved W, Opland V, Frihagen F, Jervidalo T, Madsen JE, Nordsletten L. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures. Clin Orthop Relat Res. 2009;467(9):2426-35.
4. Frenken MRM, Schotanus MGM, van Haaren EH, Hendrickx R. Cemented versus uncemented hemiarthroplasty of the hip in patients with a femoral neck fracture: a comparison of two modern stem design implants. Eur J Orthop Surg Traumatol. 2018;28:1305-12.
5. Khorami M, Arti H, Aghdam AA. Cemented versus uncemented hemiarthroplasty in patients with displaced femoral neck fractures. Pak J Med Sci. 2016;32(1):44.
6. Kong X. Meta-analysis of the effect of cemented and uncemented hemiarthroplasty on displaced femoral neck fracture in the elderly. Exp Ther Med. 2020;20(3):2173-83.
7. Kumar P, Rajnish RK, Neradi D, Kumar V, Agarwal S, Aggarwal S. Hemiarthroplasty for neck of femur fractures: to cement or not? A systematic review of literature and meta-analysis. Eur J Orthop Surg Traumatol. 2019;29:731-46.
8. Langslet E, Frihagen F, Opland V, Madsen JE, Nordsletten L, Figved W. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: 5-year follow-up of a randomized trial. Clin Orthop Relat Res. 2014;472:1291-9.
9. Li L, Zhao X, Yang X, Yang L, Xing F, Tang X. Cemented versus uncemented hemiarthroplasty for the management of femoral neck fractures in the elderly: a meta-analysis and systematic review. Arch Orthop Trauma Surg. 2021;141:1043-55.
10. Li N, Zhong L, Wang C, Xu M, Li W. Cemented versus uncemented hemiarthroplasty for femoral neck fractures in elderly patients: a systematic review and meta-analysis of randomized controlled trials. Medicine. 2020;99(8):e19039.
11. Lin FF, Chen YF, Chen B, Lin CH, Zheng K. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: A meta-analysis of randomized controlled trials. Medicine. 2019;98(8):e14634.
12. Luo X, He S, Li Z, Huang D. Systematic review of cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures in older patients. Arch Orthop Trauma Surg. 2012;132(4):455-63.

ISBN Number: 978-93-88136-57-0

13. Ning GZ, Li YL, Wu Q, Feng SQ, Li Y, Wu QL. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: an updated meta-analysis. Eur J Orthop Surg Traumatol. 2014;24:7-14.
14. Prashanth YS, Niranjan M. Comparative study of surgical management of fracture neck of femur with cemented versus uncemented bipolar hemiarthroplasty. J Clin Diagn Res. 2017;11(2):RC17.
15. Wu X, Wang Y, Sun W, Tan M. Cemented and uncemented hemiarthroplasty for femoral neck fracture in elderly patients: a systematic review and meta-analysis. Aging Clin Exp Res. 2021;33:2087-111.

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COMPARATIVE PERSPECTIVES ON INDIAN AND WESTERN LITERATURE

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ABSTRACT

Comparative literature studies the literary traditions beyond the boundaries of culture, language, and geography. Indian literature and Western literature are both products of different cultures; however, they study themes that can be found in universal human nature including identity, love, morals, nature, suffering, freedom, and social interaction. The present study will conduct a comparison between Indian and Western literary traditions in the context of their philosophical roots, thematic preoccupations, portrayal of society, as well as representation of nature and human identity. While Indian literature often deals with the notions such as dharma, karma, spirituality, and collectiveness, Western literature is known for its focus on individualism, human action, rationalism, and existential preoccupation. At the same time, these two traditions have many features in common. Using the qualitative comparative methodology, this study will analyze their similarities and differences, cultural interaction, and common human issues.

Keywords: *Comparative Literature, Indian Literature, Western Literature, Cultural Studies, Literary Traditions, Identity, Modernity, Intercultural Dialogue*

1. INTRODUCTION

Literature is one of the greatest expressions of human experience. The aims, conflicts, values, concerns, fears, beliefs, changes in societies, and in individuals are captured in literature. While literature arises in historical and cultural contexts, much of its essential concerns are universal in nature. Universal human issues such as the meaning of human life, morality, love, death, freedom, social justice, identity, and the relation between human beings and nature are common in literature. Comparing Literature is an intellectual discipline within which this similarity and difference between various literatures may be studied.

Indian and Western literatures are two great literary traditions with a wide diversity internally. They have come into existence after going through complex processes of history. Indian literature comprises classical Sanskrit literature in addition to rich literature in Hindi, Bengali, Tamil, Telugu, Malayalam, Marathi, Urdu, Kannada, Punjabi, Assamese, Odia, and in many other languages. In the case of Western literature, it has got its tradition from the Greek and Roman literature, followed by European medieval literature,

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Renaissance literature, Enlightenment literature, Romantic literature, Modernist literature, Post-modern literature and modern literature. Thus neither Indian literature nor Western literature is a homogenous concept.

Philosophical and religious concepts like dharma, karma, moksha, bhakti, compassion, cosmic order, and individual's relation to wider social and spiritual world have constituted Indian literary tradition till now. Mahabharata, Ramayana, Panchatantra, and Abhijnanasakuntalam are some examples of classical Indian literature which show the importance of ethical, social, emotional, and philosophical aspects in literary traditions. But Indian literary traditions were enlarged later by devotional literature, colonial literature, nationalist literature, progressive literature, Dalit literature, feminist literature, regional literature, and post-colonial literature.

On the other hand, Western literary tradition arose through several intellectual movements like Classical Humanism, Christianity, the Renaissance, the Enlightenment, Romanticism, Realism, Modernism, and Post-modernism. Literary writings of Homer, Sophocles, Dante, Shakespeare, Goethe, Wordsworth, Dostoevsky, T. S. Eliot, Virginia Woolf, and Toni Morrison etc., give an idea of Western approach to human nature, society, morality, history, and identity.

In this way the interaction between Indian and Western literary traditions came into significance in the colonial period due to English education, translation, printing, missionary activities, and intellectual exchange. This interaction brought about influence of European literary tradition on Indian writers. Indian philosophical and literary tradition has also influenced Western intellectuals and writers. Rabindranath Tagore, Sri Aurobindo, Mahatma Gandhi and some other postcolonial writers have made contributions to the literary interaction between India and the West.

1.1 Theoretical Framework

Comparative Literature Theory forms the theoretical framework of the present study because it offers an effective methodology for the analysis of literary texts from the perspective of cultural and historical diversity of literature in different cultures and languages. Moreover, the present study also employs Cultural Theory, Postcolonial Theory, and Reception Theory to analyze the relationship between Indian and Western literary traditions. Comparative Literature Theory helps identify similarities, differences, and relations between the two literary traditions in terms of their influences and thematic concerns. Cultural Theory emphasizes the role of literature as the reflection of society's values, beliefs, customs, and identities.

ISBN Number: 978-93-88136-57-0

Postcolonial Theory becomes especially useful in analyzing the historic relationship between India and the West in terms of colonization, culture, identity, and resistance. Reception Theory becomes helpful in interpreting Indian and Western literary texts from the perspective of their reception by the readers from various cultural environments. Altogether, the mentioned theoretical perspectives become useful in analyzing themes of identity, morality, nature, individualism, spirituality, social justice, and cultural interactions. In other words, the framework of the present study approaches Indian and Western literatures as interacting literary cultures rather than separate traditions.

1.2 Objectives of the Study

The major objectives of the study are:

1. To examine the major characteristics of Indian and Western literary traditions.
2. To compare their philosophical and aesthetic foundations.
3. To analyze similarities and differences in their representation of human identity and society.
4. To examine the treatment of nature, morality, love, suffering, and social conflict.
5. To study the influence of cultural interaction between India and the West.

2. REVIEW OF LITERATURE

Shrawan (2019) considered the interplay between the language of literary works and their meanings by analyzing Indian and Western aesthetical traditions comparatively. The analysis focused on the creation of meaning through the use of language, cultural background, aesthetical ideas, and philosophical assumptions. Indian and Western approaches to literary criticism were compared and contrasted. The study indicated that Indian aesthetic theory has paid much attention to such notions as emotion, beauty, art, and the interrelation between literary work and aesthetic perception of a reader. In turn, Western aesthetical theory evolved through several philosophical eras – classical theories of imitation, humanism, romanticism, modernism, and criticism. Shrawan pointed out that literary meanings cannot be separated from cultural context in which a literary work was written. Comparison has proven helpful in finding out both differences and similarities between Indian and Western literary criticism.

Singh and Iyer (2016) introduced the concept of South Asian literatures outside the conventional framework of Anglophone studies. In their study, the two pointed out the shortcomings of the methods which focused mainly on literary production written in English and the need to understand the multi-

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linguistic nature of South Asian literature. They pointed out that the South Asian literary tradition had been developed in several regional languages, cultures, oral and literary traditions. They also highlighted the importance of comparative methodologies in including Hindi, Bengali, Tamil, Urdu, Malayalam, Kannada and other literary traditions into wider academic discourses. Their study implied that the comparative literature did not have to be limited to either national frontiers or dominant language but rather looked at the flow of ideas, themes, forms and cultural experience among different linguistic and geographical borders. The study further showed that the comparative South Asian literature offered the chance to look at cultural interactions and historical experiences while preserving the uniqueness of each literary tradition.

Dubey (2026) studied the connection between Indian and Western interpretive traditions in Hindu literary theory. The research investigated the influences of Indian literary interpretation through philosophical and aesthetic ideas distinct from the prevailing Western ideas. It emphasized the significance of Indian intellectual tradition in relation to literary meaning, interpretation, spirituality, and aesthetic experience. The research pointed out that the Indian literary tradition was formed through the close association of literature with philosophy, religion, ethics, and aesthetics. On the other hand, Western interpretive traditions introduced different methods of analyzing, criticizing, representing, and understanding the meaning of texts. Dubey studied the interaction between both interpretive traditions and showed how comparative interpretation could help understand literary theory better. The research also proved that Indian literary ideas have to be considered in their own intellectual and cultural context and not solely through Western theories.

Princy (2026) The study involved investigating cross-cultural perspectives in literature through comparative method. The study focused on how culture, values, history, and language impacted literature. The study highlighted that literature was not only an expression of personal creativity, but it also reflected the culture in which the reader and writer lived. The study focused on how texts of literature from other cultures can help in understanding the unique culture and the common experiences of mankind. The themes included identity, social relations, cultural values, human feelings, and intercultural relations. The study showed that comparative literary study allowed readers to get out of the limited scope of their own culture and take a broader view of literature.

3. CONCEPTUAL FRAMEWORK OF COMPARATIVE LITERATURE

Comparative literature deals with cross-linguistic, cross-cultural, cross-national, and cross-disciplinary study of literature. Comparative literature is not just a method of comparing two literary works to find out

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similarities and dissimilarities but also explores relations, influences, history, cultural interactions, forms of reception and different ways of representing human experience.

The comparative method undermines the concept of isolation of literature within national boundaries. Literature is always in circulation crossing languages and cultures due to translation, adaptation, migrations, education, publications and intellectual contacts. Hence, one literary text can be at once part of multiple cultural dialogues.

A comparative study of Indian and Western literature involves consideration of three main aspects. First, it is necessary to take into account the context of each literary text. Secondly, comparison should take into account internal diversity of both literary traditions. Thirdly, similarity cannot always be regarded as an influence because the same literary themes can occur independently from human experiences. The comparative model used in this paper includes comparative literary criticism, cultural studies, post-colonial studies and textual analysis.

4. PHILOSOPHICAL FOUNDATIONS OF INDIAN AND WESTERN LITERATURE

One of the major points of comparison is the philosophical basis of these two traditions. Indian literary philosophy evolved with the philosophical theories about dharma, karma, moksha, consciousness, and individual place in the universe. It is noteworthy that in literature, there is much consideration of ethical and spiritual matters and they are not separated from the aesthetical experience.

The Indian notion of rasa is especially crucial for the analysis of classical Indian aesthetics. Rasa can be seen as an aesthetical experience, which was obtained through artistic imitation and it was developed to its maximum in Bharata's Natyashastra. Hence, the accent is not put on the imitation of reality but the emotion and meditations of the spectators created during the art.

The Western literary theory followed another way of evolution. It includes debates about imitation, representation, poetry, and drama set up by Plato and Aristotle. The latter provided his own systematic theory of tragedy, plot, catharsis, and recognition. Western literary tradition included the Christian theology, Renaissance humanism, rationalism of the Enlightenment, individualism of Romanticism, modern fragmentation and post-modern skepticism.

Hence, while Indian aesthetics emphasized aesthetic experience, emotional realization, ethical order and connectedness, Western literary tradition had the traditions of imitation, representation, individual

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initiative, rationality, and psychological analysis. Yet, this difference is only tendency not a clear line of division.

5. REPRESENTATION OF THE INDIVIDUAL AND SOCIETY

The connection between the individual and society has been an issue of great importance in Indian and Western literature alike. It has only been interpreted very differently in most cases.

Indian literature, in its classical sense, has usually positioned the individual within a web of familial, societal, ethical, and cosmological duties and responsibilities. Dharma has created obligations associated with social and ethical order. Individuals in the Mahabharata face situations wherein there is often a clash between individual aspiration and social/ethical duty.

The Western literary tradition too explores the dichotomy between the two but individual freedom comes to occupy an increasingly prominent position in the Renaissance, Romantic, Modernist, and contemporary phases of literature. In Shakespeare's plays, individual aspiration is opposed by the power structure around him. The Romantic poets glorified individual imagination and emotions, and the Modernists explored the subjectivity of consciousness and alienation.

This difference, therefore, cannot be seen as one of collectivism versus individualism in the full sense but rather one of different areas of emphasis. While Indian traditions have been more concerned with relational identity, Western traditions have been preoccupied with individual consciousness.

5.1 Suffering, Morality, and Human Conflict

Suffering is a universal literary theme. In Indian literature, suffering is linked with problems related to ethics, karma, attachment, duty, and spiritual knowledge. The Mahabharata is special as the characters in this text face moral dilemmas that do not have easy answers.

In western literature too, suffering is examined through tragedy, existential dilemma, personal crisis, religious dilemma, and social oppression. Greek tragedy presents the theme of suffering as something brought about by fate, mistake, clash, and human imperfection. In modern literature, suffering is turned into themes of alienation, meaninglessness, identity, and uncertainty of modern life. The two forms of literature thus make use of suffering as an instrument of exploring human imperfections and ethical decision-making.

5.2 Social Justice and Marginalized Voices

ISBN Number: 978-93-88136-57-0

Contemporary Indian literature has given voice to marginalized groups such as Dalits, tribes, workers, and women.

Western literature also has a rich tradition of literature that has represented marginalized groups in society. Feminist literature, African American literature, postcolonial literature, worker's literature, and contemporary minorities' literatures have questioned the existing canons of literature.

The comparative approach shows that literature can be employed as a tool of social criticism. Authors of both traditions use literary means to criticize existing systems and make their voices heard by the dominant culture.

5.3 Colonialism, Modernity, and Cultural Encounter

The colonial experience radically altered the interaction between Indian and Western literary traditions. Education provided by the British colonial government exposed Indian thinkers to European literary traditions, English language education, printing, and Western philosophies. Indian writers would then appropriate, alter, and contest these traditions in response to their own cultural milieus.

A significant case for cross-cultural literary engagement is that of Rabindranath Tagore. Tagore's writings were produced out of Indian philosophical and cultural traditions but also addressed international literary audiences. The international acclaim he achieved is testament to how translation facilitates dialogue between literary traditions.

Indian English literature went on to become a significant tradition through the writings of writers like R. K. Narayan, Mulk Raj Anand, Raja Rao, Salman Rushdie, Amitav Ghosh, Arundhati Roy, and many others. The questions of identity, colonialism, migration, nationalism, globalization, and cultural hybridity are among those they have explored.

Finally, writers and thinkers in the West have engaged with Indian philosophy, religion, literature, and culture. This engagement demonstrates that influence in literature need not be unidirectional. Culture is exchanged through processes of adaptation, resistance, and re-interpretation.

6. CONCLUSION

A comparative study of Indian literature and Western literature shows that although these two bodies of literature come from different cultures, philosophy, and history, they all deal with some basic aspects of human life. Indian literature usually involves elements like spirituality, ethics, interpersonal relations, and

unity with nature, whereas Western literature is more concerned with individuality, freedom, reason, and existence. Nevertheless, this dissimilarity does not mean the total separation since the two bodies of literature deal with similar problems of love, suffering, morality, social inequality, and search for meaning. The study also proves that translation, colonization, globalization, and intercultural exchanges have made these two bodies of literature interact even more than before. Hence, comparative literature offers an efficient tool for studying not only cultural particularities but also common human experiences.

REFERENCES

1. Boyden, Jo. "Childhood and the Policy Makers: A Comparative Perspective on the Globalization of Childhood." *Constructing and Reconstructing Childhood*, Routledge, 2015, pp. 167–201.
2. Dubey, V. "The Interplay of Indian and Western Interpretative Traditions in Hindu Literary Thought." *Journal of Sanatana Dharma*, vol. 1, no. 2, 2026, p. 61.
3. Fägerlind, Ingemar, and Lawrence J. Saha. *Education and National Development: A Comparative Perspective*. Elsevier, 2016.
4. Gidron, Noam, James Adams, and Will Horne. *American Affective Polarization in Comparative Perspective*. Cambridge UP, 2020.
5. Massey, Douglas S. "Economic Development and International Migration in Comparative Perspective." *Determinants of Emigration from Mexico, Central America, and the Caribbean*, Routledge, 2019, pp. 13–47.
6. Panda, K. "Indian and Western Philosophy: A Brief Comparative Study." *International Journal of Multidisciplinary Horizon*, vol. 2, no. 1, 2025, pp. 41–47.
7. Pimpale, V. B. "Exploring Perspectives of India: A Comparative Analysis between Native and Diasporic Writers."
8. Princy, A. T. "Cross-Cultural Perspectives in Literature: A Comparative." *Frontiers in Social Sciences Research*, 2026, pp. 1–8.
9. Shrawan, A. *The Language of Literature and Its Meaning: A Comparative Study of Indian and Western Aesthetics*. Cambridge Scholars Publishing, 2019.
10. Singh, A., and N. Iyer. "Introduction: Beyond the Anglophone—Comparative South Asian Literatures." *Comparative Literature Studies*, vol. 53, no. 2, 2016, pp. 209–224.
11. Singh, S. "The Theory of Imitation: A Comparative Study of Indian and Western Perspectives." *Journal of Comparative Literature and Aesthetics*, vol. 46, no. 2, 2023, pp. 24–33.

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Improving Surgical Results for Distal Radius Fractures: Internal Fixation with Volar Locking Compression Plate and Open Reduction

Vivek Pal
Research Scholar

Abstract

Background

One of the most frequent orthopedic fractures is a distal radius fracture, which necessitates surgical intervention for optimal functional rehabilitation. Data on the post-operative results, complications, and functional outcome of the widely used procedure of open reduction and internal fixation using the volar locking compression plates (VLCP) are still required to assess its efficacy.

Aim

In order to assess the safety and effectiveness of the procedure, this study will ascertain the intraoperative and postoperative problems as well as the recovery to function of patients who had treatment for distal radius fractures using ORIF with VLCP.

Methods

Eighty adult patients (18–80 years old) receiving ORIF with VLCP participated in a 12-month prospective observational study at the Department of Orthopaedics, All India Institute of Medical Sciences, Patna, Bihar, India. At six weeks, three months, and six months after surgery, measurements were made for intraoperative factors, postoperative complications, and functional return as measured by the Mayo Wrist Score and the Disabilities of the Arm, Shoulder, and Hand (DASH) Score. SPSS and R software were used to calculate statistical inferences based on the significance level of $p < 0.05$.

Results

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12.5% of patients had post-operative morbidity, with tendinitis (5.0%) and surgical wound infection (7.5%) being the most prevalent. In terms of DASH and Mayo Wrist Score, 75.0% of patients had good or excellent function at the six-month follow-up, while 25.0% had mediocre or poor improvement. The results show that ORIF with VLCP restores wrist function with a low rate of problems, however this is dependent on patient-related factors such bone quality and rehabilitation compliance.

Conclusion

ORIF with VLCP is a good and safe form of treatment of distal radius fracture with desirable functional results and a low risk of postoperative complications. This research highlights attention to proper positioning of the implants, infection management, and an early rehabilitation strategy as key principles for maximizing recovery of the patient. Long-term studies and more patient-specific rehabilitative strategies may help improve function across a heterogeneous group of patients.

Keywords: Distal Radius Fractures, Open Reduction and Internal Fixation, Volar Locking Compression Plate, Surgical Outcomes, Functional Recovery, Post-Operative Complications, DASH Score, Mayo Wrist Score, Orthopedic Surgery, Rehabilitation.

1.INTRODUCTION

One of the most frequent orthopedic injuries is a distal radius fracture, which frequently necessitates surgery to restore wrist function and avoid long-term consequences. Because it can offer stable fixation, early mobilization, and better functional results for patients with unstable or displaced fractures, open reduction and internal fixation (ORIF) with a volar locking compression plate (VLCP) has been a preferred treatment [1].

In their management, anatomical reduction and stable internal fixation are of utmost significance in their potential to lead to the optimal outcome in healing and avoid complications such as malunion, stiffness, and post-traumatic arthritis. Volar approach is very advantageous with features such as softer tissue preservation, less tendon irritation, and greater biomechanical stability, and thus the usual practice in modern-day orthopedic practice [2].

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1. **Biomechanical Stability and Healing Efficiency**

- VLCPs are intended to achieve angular stability, which improves fracture fixation, especially in osteoporotic bone. Their fixed-angle construct avoids collapse and secondary displacement, essential for early functional rehabilitation.
- Relative to classic dorsal plating, the volar method lessens the potential for irritation of the extensor tendon and more predictably enables post-operative results [3].

2. **Clinical and Functional Outcomes**

- ORIF with VLCP has been correlated with enhanced range of motion, grip strength, and patient satisfaction. Research indicates that surgical correction earlier in the process yields quicker recovery times and lower complication rates with regard to nonunion or hardware complications.
- Rehabilitation protocols post-operatively stress early mobilization of the wrist to avoid stiffness and improve long-term function, further underlining the value of stable internal fixation [4].

Finding the efficacy of ORIF in conjunction with volar locking compression plates for the surgical treatment of distal radius fractures is the aim of the current study. The study aims to offer insights into enhancing the treatment process in the rehabilitation of the patient's life and functional abilities based on biomechanical stability, post-operative function, and complication rate [5].

Methodology

Study Design

This potential observational study was carried out at the All India Institute of Medical Sciences' Department of Orthopaedics in Patna, Bihar, India, over the course of a year. In the event of distal radius fractures, this was done in order to compare recovery functions, surgical results, and complications, such as the rate of open reduction and internal fixation with the aid of volar locking compression plates (VLCP).

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Study Population

Inclusion Criteria:

1. Adult patients (18–80 years) with distal radius fractures that are open to surgical treatment.

2. Patients with ORIF using VLCP during the study period.

3. Those who gave informed consent for inclusion and follow-up evaluations.

Exclusion Criteria:

1. Patients with missing medical records or poor post-operative follow-up.

2. Those with open fractures (Gustilo-Anderson Grade II and III) or neurovascular complications.

3. Patients with advanced comorbidities that will disrupt fracture healing and recovery.

Sample Size

The study included 80 patients who satisfied the inclusion requirements. ORIF used VLCP to operate on each patient, and they were monitored for problems, function, and fracture healing during the post-operative phase.

Data Collection

1. Post-Operative and Intraoperative Parameters:

- Intraoperative complication data, surgical time, and blood loss were obtained.
- Post-operative parameters like radiographic union, range of motion, and pain score were assessed at regular intervals.

2. Functional Evaluation:

- To measure functional recovery, the patients were assessed using the Mayo Wrist Score and the Disabilities of the Arm, Shoulder, and Hand (DASH) Score.
- At six weeks, three months, and six months after surgery, range of motion and grip strength were contrasted with the unaffected hand on the other side.

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3. Complications and Follow-Up:

- We monitored complications such infection, hardware failure, tendon irritation, and loss of fracture reduction.
- Follow-up exams with radiographic and clinical evaluation were performed at two, six, three, and six months after surgery.

Outcome Measures

1. Primary Outcomes:

- Radiological proof of healing of the fracture and preservation of reduction.
- Improvement in function measured using DASH and Mayo Wrist Scores.

2.Secondary Outcomes:

- Frequency of post-operative complications in the form of infections, implant problems, and stiffness of the wrist.
- Time elapsed before return to normal activities and employment.

Statistical Analysis

- R and SPSS statistical software were used for the analysis.
- Descriptive Statistics: To summarize clinical and demographic data, mean, standard deviation, and percentages were used.
- Chi-Square Test: Used to compare how patient characteristics and post-operative outcomes relate to one another.
- ANOVA and the student's t-test are used to compare functional scores at different follow-up times.
- A statistically significant p-value was defined as less than 0.05.

Results

The breakdown of post-operative complications among patients treated for distal radius fractures with ORIF utilizing a volar locking compression plate is displayed in Table 1.

ISBN Number: 978-93-88136-57-0

Table 1: Post-Operative Complications and Frequency

Among the 80 patients, 12.5% (10 patients) experienced complications, including surgical site infections (SSI) and tendon irritation, whereas 87.5% (70 patients) had no reported complications.

Table 1. Post-Operative Complications and Frequency

Post-Operative Complications	Number	Percentage (%)
Surgical Site Infection (SSI)	6	7.5%
Tendon Irritation	4	5.0%
None	70	87.5%
Total	80	100.0%

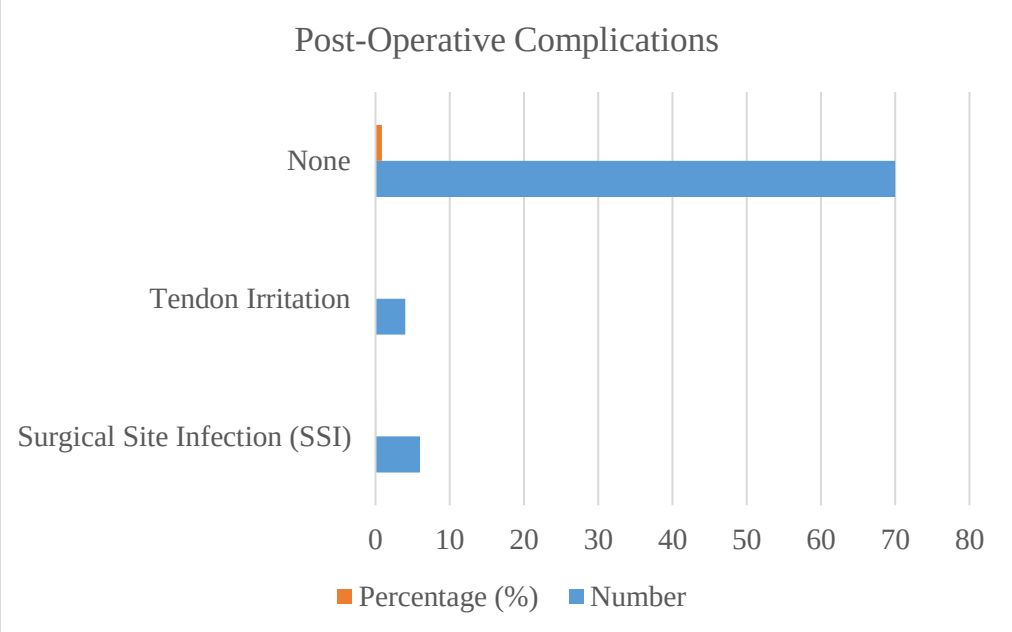


Figure 1: Graphical Representation on Post-Operative Complications and Frequency

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The results show that post-operative complication rate was quite low, with SSI being noted in 7.5% of patients only. This infers that attention to surgical detail, infection prevention protocols, and post-operative treatment are all reflected in good outcomes from surgery. Tendon irritation, a complication of volar plating that is well-known, was seen in 5.0% of patients and points to attention to plate position and patient-related anatomical variables. The low rate (87.5%) of complication-free patients proves the efficacy and safety of this procedure.

Table 2 illustrates the functional recovery of patients according to the Mayo Wrist Score and DASH Score at six months after surgery.

Table 2: Functional Outcomes at 6-Month Follow-Up

A majority of patients (75.0%) achieved excellent or good functional outcomes, indicating successful restoration of wrist function, while 25.0% had fair or poor outcomes.

Table 2. Functional Outcomes at 6-Month Follow-Up

Functional Outcome	**Number**	**Percentage (%)**
Excellent (Mayo Score >90, DASH <10)	40	50.0%
Good (Mayo Score 75-89, DASH 10-20)	20	25.0%
Fair (Mayo Score 60-74, DASH 21-40)	12	15.0%
Poor (Mayo Score <60, DASH >40)	8	10.0%
Total	80	100.0%

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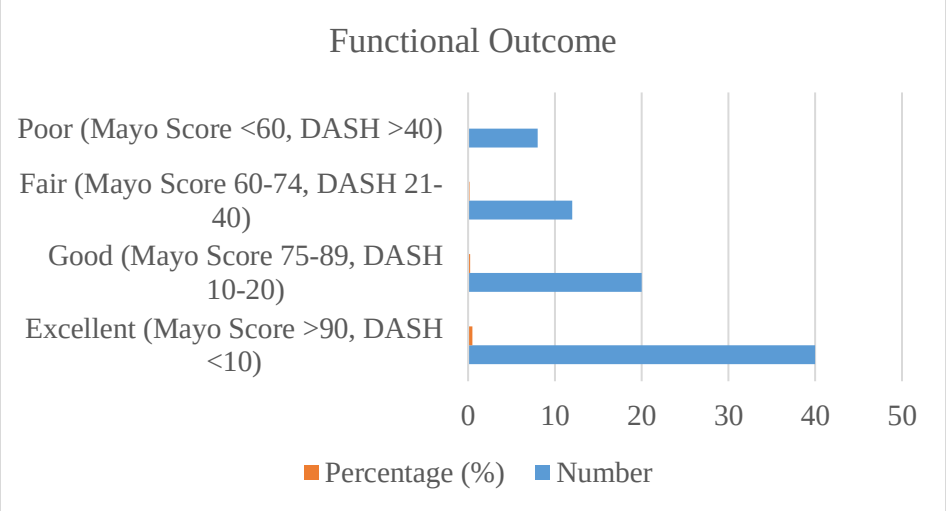


Figure 2: Graphical Representation on Functional Outcomes at 6-Month Follow-Up

The outcomes indicate that most patients (75.0%) had satisfactory functional results, excellent or good wrist function at six months after surgery. Fewer patients (15.0%) had fair results, perhaps due to delayed rehabilitation, stiffness, or minimal residual pain. Poor results (10.0%) can be attributed to patient age, bone quality, or soft tissue injury. In general, the evidence is in favor of ORIF with volar locking compression plates for functional recovery, with the majority of patients regaining significant wrist mobility and strength.

Discussion

This study evaluated the surgical and functional outcomes of using volar locking compression plates (VLCP) in conjunction with open reduction and internal fixation (ORIF) for fractures of the distal radius. According to the findings, the majority of patients have good functional recovery and low rates of post-operative complications [6].

Post-Operative Complications and Infection Rates

1. Surgical Site Infections (SSI):

- This research identified that 7.5% of patients developed SSI, a lower percentage than in some earlier reports of orthopedic implant-related infections.

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- The low rate of SSI indicates that careful adherence to infection control practices, prophylactic antibiotics, and sterile surgical practices contributed significantly to minimizing infection risk [7].
- Adequate post-operative wound care and prompt infection detection are still important to prevent complications and achieve optimal patient recovery.

2. Tendon Irritation and Hardware-Associated Complications:

- The incidence of tendon irritation in 5.0% of cases is evidence of the mechanical complications of volar plating [8].
- This can be due to incorrect placement of the plate, screw prominence, or patient anatomical differences [9].
- These can be avoided through intraoperative attention and rehabilitation after surgery, enhancing patient comfort and mobility.

Functional Outcomes and Recovery

1. Analysis of Mayo Wrist and DASH Score:

- The research noted that 75.0% of patients had excellent or good functional results at six months after surgery.
- This implies that VLCP offers stable fixation, enabling early mobilization of the wrist and functional rehabilitation [10].
- The other 25.0% of patients with poor or fair results could have been affected by delayed rehabilitation, pre-operative conditions, or differences in capacity to heal [11].

2. Early Mobilization Effect:

- The results highlight the need for an early rehabilitation regimen to avoid stiffness and enhance wrist function [12].
- Lower functional scores patients might be helped with more individualized physical therapy regimens with grip strength and range of motion exercises.

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Clinical Implications and Recommendations

1.Optimizing Surgical Technique:

- Surgeons would emphasize accurate placement of the plates to avoid hardware-related complications as well as the risk of irritation of the tendon [13].
- Follow-up with radiographs at regular intervals can identify earlier signs of complication related to implant.

2.Post-Operative Infection Control and Care:

- Enhancing the infection control techniques, such as the use of prophylactic antibiotics judiciously and application of strict sterilization protocols, can further lessen SSI rate [14].
- Early interventions must be executed for patients developing delayed functional improvement.

3.Future Directions for Research

- Multicenter studies with larger samples can confirm these results and yield more generalized advice [15].
- Investigation into patient-specific factors influencing functional recovery can lead to better personalized treatment planning.

Strengths and Limitations

Strengths:

• The Research offers valuable information regarding post-operative complications and functional results after VLCP fixation.

• Use of validated functional scoring systems (Mayo Wrist Score and DASH) helps in objective determination of functional recovery.

Limitations:

• The single-center location might confine the study results to a wider population.

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• A more prolonged follow-up will offer richer information regarding long-term results and the longevity of implants.

Conclusion

This research shows that open reduction and internal fixation (ORIF) with volar locking compression plates (VLCP) is a consistent and effective operative treatment for distal radius fractures. The minimal frequency of postoperative complications, most notably surgical site infections (7.5%) and tendon irritation (5.0%), supports the significance of sound surgical technique and infection prevention practices in the best outcomes of patients. In addition, functional recovery evaluations show that 75.0% of patients had excellent or good wrist function at six months after surgery, further supporting the effectiveness of VLCP in restoring wrist strength and mobility. The results highlight the significance of precise implant placement, early rehabilitation, and patient-specific factors to reduce complications and improve post-operative recovery. Future studies would address long-term functional outcomes, satisfaction from the patients' perspectives, and efforts aimed at reducing further post-operative morbidity in managing distal radius fractures.

REFERENCES

1. Chen M., Gittings D. J., Yang S., Liu G., Xia T. Variable-angle locking compression plate fixation of distal radius volar rim fractures. *The Iowa Orthopaedic Journal*, 39(2), 55. (2019).
2. Deng Z., Wu J., Tang K., Shu H., Wang T., Li F., Nie M. In adults, early mobilization may be beneficial for distal radius fractures treated with open reduction and internal fixation: a systematic review and meta-analysis. *Journal of Orthopaedic Surgery and Research*, 16, 1-18. (2021).
3. Fu Q., Zhu L., Yang P., Chen A. Volar locking plate versus external fixation for distal radius fractures: a meta-analysis of randomized controlled trials. *Indian Journal of Orthopaedics*, 52, 602-610. (2018).
4. García-Cepeda I., Aguado-Maestro I., De Blas-Sanz I., Quintanilla-García A., García-Alonso M. Radiological results of surgical management of fracture of the distal radius treated with volar locking plates. *Injury*, 51, S42-S47. (2020).

ISBN Number: 978-93-88136-57-0

5. Ghaddaf A. A., Abdulhamid A. S., Alomari M. S., Alquhaibi M. S., Alshehri A. A., Alshehri M. S. Comparison of immobilization periods following open reduction and internal fixation of distal radius fracture: A systematic review and meta-analysis. *Journal of Hand Therapy*, 36(1), 23-32. (2023).
6. Liu X., Miramini S., Patel M., Liao J., Shidid D., Zhang L. Influence of therapeutic grip exercises induced loading rates in distal radius fracture healing with volar locking plate fixation. *Computer Methods and Programs in Biomedicine*, 215, 106626. (2022).
7. Loisel F., Kielwasser H., Faivre G., Rondot T., Rochet S., Adam A., Lepage D. Treatment of distal radius fractures with locking plates: an update. *European Journal of Orthopaedic Surgery & Traumatology*, 28, 1537-1542. (2018).
8. Maccagnano G., Noia G., Vicenti G., Baglioni M., Masciale M. R., Cassano G. D., Pesce V. Volar locking plate versus external fixation in distal radius fractures: A meta-analysis. *Orthopedic Reviews*, 13(1), 9147. (2021).
9. Nwosu C., Rodriguez K., Zeng S., Klifto K. M., Klifto C. S., Ruch D. S. Complications following volar locking plate fixation of distal radius fractures in adults: a systematic review of randomized control trials. *The Journal of Hand Surgery*, 48(9), 861-874. (2023).
10. Quadlbauer S., Pezzei C., Jurkowitsch J., Rosenauer R., Pichler A., Schättin S., Leixnering M. Functional and radiological outcome of distal radius fractures stabilized by volar-locking plate with a minimum follow-up of 1 year. *Archives of Orthopaedic and Trauma Surgery*, 140, 843-852. (2020).
11. Quadlbauer S., Pezzei C., Jurkowitsch J., Rosenauer R., Pichler A., Schättin S., Leixnering M. Early complications and radiological outcome after distal radius fractures stabilized by volar angular stable locking plate. *Archives of Orthopaedic and Trauma Surgery*, 138, 1773-1782. (2018).
12. Ravinath T. M., Shariff S. M., Agarwal N., Rajendra P., Mendiratta D. A prospective study in surgical management of distal end radius fracture with variable angle locking compression plate. *International Journal of Orthopaedics*, 7(1), 703-712. (2021).

ISBN Number: 978-93-88136-57-0

13. Singh S., Chhabra A., Kumar A., Tank S., Sahu V. K. Functional and radiological outcomes of volar locking compression plate in surgical management of fractures of distal end radius. *International Journal of Orthopaedics Sciences*, 5(2), 50-54. (2019).
14. Synek A., Baumbach S. F., Pahr D. H. Towards optimization of volar plate fixations of distal radius fractures: Using finite element analyses to reduce the number of screws. *Clinical Biomechanics*, 82, 105272. (2021).
15. Wilson J., Viner J. J., Johal K. S., Woodruff M. J. Volar locking plate fixations for displaced distal radius fractures: an evaluation of complications and radiographic outcomes. *Hand*, 13(4), 466-472. (2018).

Emerging Perspectives in Science,
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ASSESSMENT OF FUNCTIONAL OUTCOMES FOLLOWING OPEN REDUCTION AND INTERNAL FIXATION OF DISTAL FEMUR FRACTURES USING LOCKING COMPRESSION PLATES

Devendra Verma
Research Scholar

Background

Distal femur fractures are difficult to manage because of their severity, especially in osteoporotic bone or comminuted fracture cases. Locking compression plates (LCPs) have proved to be a dependable way to facilitate stable fixation and early mobilization, but functional outcomes and complications need further assessment.

Introduction

The goal of this study is to compare the radiographic and functional outcomes of LCP open reduction and internal fixation for fractures of the distal femur. This study aims to analyse the treatment's effectiveness and identify areas for postoperative care improvement by comparing union rate, range of motion (ROM), Knee Society Score (KSS), and complications.

Method

A prospective observational study was carried out on 60 patients (38 men, 22 women; mean age 47.5 ± 12.3 years) with AO/OTA Type 33A and 33C distal femoral fractures. ORIF with LCPs was performed in the patients, and structured rehabilitation followed. Clinical and radiological evaluations, such as union rates, KSS, and ROM, were done at 6, 12, and 24 weeks. Infection, stiffness, and delayed union were noted as complications. Descriptive statistics and repeated-measures ANOVA were used to analyse the data.

Results

Radiological union in 90% of fractures was seen at 24 weeks with a notable increase in KSS from 60 ± 8.2 at 6 weeks to 85 ± 12.1 at 24 weeks. Mean ROM ranged from 50° at 6 weeks to 120° at 24 weeks. Infection (8%), stiffness (12%), and delayed union (5%) were seen as complications and were treated accordingly. Malalignment had come down from 5% at 6 weeks to 2% at the last follow-up.

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Discussion

The research supports the effectiveness of LCPs in the treatment of distal femur fractures with excellent functional and radiological results. Early mobilization, made possible by secure fixation, played a key role in rehabilitation. Stiffness and infection remain issues, calling for emphasis on physiotherapy and careful surgery. The evidence is in keeping with other findings that lock plates are advantageous for complex fractures.

Conclusion

Locking compression plates offer a secure and effective way of managing distal femur fractures, with high union rates, better functional scores, and excellent recovery of range of motion. Although the complications were few, organized rehabilitation and careful post-operative monitoring are necessary to maximize outcomes. More research with larger series and longer follow-up is needed to confirm these results.

Keywords: Distal femur fractures, locking compression plates, open reduction and internal fixation, Knee Society Score, range of motion, fracture union, post-operative complications.

1. INTRODUCTION

Distal femur fractures are multifaceted injuries with formidable challenges in orthopedic treatment because of their close location to the knee joint, fracture pattern variability, and possibility of concomitant soft tissue injury. Distal femoral fractures are most often produced by high-energy trauma, for example, road traffic crashes in young patients, and low-energy mechanisms, for instance, falls in older patients with osteoporotic bone. Successful treatment is essential to restore knee function, preserve alignment, and facilitate early mobilization to avoid complications like stiffness and non-union.

Treatment for distal femur fractures now commonly involves open reduction and internal fixation with locking compression plates (LCPs). In order to regain function, LCPs provide angular stability, better fixation in osteoporotic bone, and regulated early weight-bearing. Yet, despite the benefits of LCPs, problems including infection, stiffness, and implant-related issues still exist.

This research seeks to examine the functional outcomes of patients who undergo ORIF using LCPs for fractures of the distal femur. The research assesses significant parameters, such as radiological union, range of motion (ROM), Knee Society Scores (KSS), and complication rates, to examine the effectiveness of this surgical technique and its influence on patient recovery

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2. RESEARCH METHOD

2.1. Study Design

The functional results of distal femoral fractures handled by open reduction and internal fixation with locking compression plates were assessed in this prospective observational study..The assessment was made of clinical and radiological parameters in a specific follow-up period, enabling thorough analysis of patterns of healing, recovery of function, and complications.

2.2. Sample Size and Patient Selection

In this study, sixty individuals who had suffered distal femur fractures were examined. Patients were selected for the sample based on predetermined criteria for inclusion and exclusion. Patients with AO/OTA classifications 33A and 33C fractures and ages between 18 and 75 were considered for inclusion. We did not include patients who had pathological fractures, Grade III open fractures, or fractures that caused neurovascular damage. The average age of the 60 patients was 47.5 ± 12.3 years, and 38 of them were male and 22 were female. The road traffic accidents accounted for the greatest mode of injury (65%) followed by 35% by falls.

2.3. Surgical Procedure

Locking compression plates were used in all of the patients' open reduction and internal fixation (ORIF) procedures. The procedures were done under spinal or general anaesthesia, depending upon the status of the patient. A uniform surgical technique was followed to achieve uniform results. The lateral route to the distal femur was adopted in all the patients, and anatomical reduction was performed with locking compression plates. The post-operative management consisted of antibiotic prophylaxis and the start of physical therapy to ensure early mobilization and functional recovery.

2.4. Follow-Up Schedule

Patients were followed up at three critical time points: 6 weeks, 12 weeks, and 24 weeks post-surgery. At 6 weeks of follow-up, early radiological evaluation and complications were monitored. At 12 weeks, intermediate results such as the advancement of fracture healing and range of motion (ROM) were evaluated. The last follow-up at 24 weeks measured long-term results such as union rates, Knee Society Scores (KSS), and general functional recovery.

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2.5. Assessment Parameters

Radiological and functional evaluation was done at each follow-up. Radiological union was cortical bridging across a minimum of three cortices on two orthogonal X-rays. Malalignment was measured in terms of angulation or displacement of the fracture fragments. The functional outcome was evaluated by Knee Society Score (KSS), which evaluates knee function as well as the level of pain. ROM was recorded with a goniometer, with emphasis on the flexion and extension of the painful knee. Complications such as infection, failure of the implant, delayed union, and stiffness were reported and treated accordingly.

2.6. Data Analysis

Data were statistically analyzed to assess functional and radiological results. Patient demographics, mechanism of injury, and fracture types were compiled in descriptive statistics. KSS and ROM changes throughout the follow-up periods were compared using repeated measures ANOVA to establish statistical significance. Healing parameters, such as union rates and malalignment, were compared throughout follow-up periods using chi-square tests. Graphic illustration of outcomes was added to supply visual information, including line charts for ROM progress, bar charts for KSS trends, and pie charts for rates of complication.

2.7. Ethical Considerations

An institutional ethics committee reviewed and approved the study's protocol, guaranteeing that it adhered to all applicable ethical standards. Before anyone could be enrolled in the study, they had to give their written, informed consent.Confidentiality of patient information was ensured throughout the research, and participation in the study was purely voluntary.

3. RESULT

3.1. Patient Demographics

The demographic profile of the study points out the most important features of the patient population with distal femur fractures. The results show that middle-aged individuals are mostly affected, with a greater incidence in males than females. Males are more likely to be affected because they have greater exposure to high-energy trauma, like road traffic accidents, which was the most common cause of injury in this study.

Table 1: Demographic Profile

Parameter	Value

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Number of Patients	60
Mean Age	47.5 ± 12.3 years
Male: Female Ratio	38:22
Mode of Injury	RTA (65%), Falls (35%)
Fracture Type (AO/OTA)	33A (55%), 33C (45%)

Falls were noted to be another substantial risk factor, mainly in older patients, where reduced bone quality and balance impairment come into play. The study also showed a pattern of fracture type, with less complex fracture types being somewhat more frequent than more complex ones. These findings highlight the necessity for focused prevention efforts, like enhanced traffic safety and fall prevention initiatives, to counteract the most important risk factors in distal femur fractures.

3.2. Fracture Healing

The healing parameters analysis emphasizes the gradual nature of healing after open reduction and internal fixation of distal femur fractures with locking compression plates. Radiological union demonstrated a gradual improvement with time, with very few fractures healing at six weeks, a majority of them uniting by 12 weeks, and almost complete union at 24 weeks.

Table 2: Healing Progress and Alignment Outcomes

Healing Parameter	**6 Weeks**	**12 Weeks**	**24 Weeks**
Radiological Union (%)	15%	65%	90%
Malalignment (%)	5%	3%	2%

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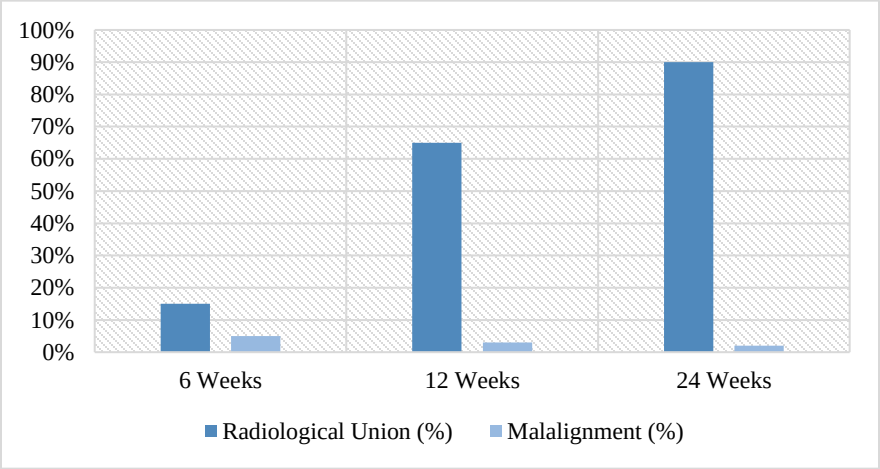


Figure 1: Healing Progress and Alignment Outcomes

This development demonstrates the stability offered by locking compression plates, enabling proper callus formation and healing of the bone. Malalignment was kept to a minimum during the follow-up period, declining progressively from the early weeks to virtually nothing by 24 weeks. This suggests the accuracy of the surgical method and the dependability of the fixation technique in ensuring correct alignment during the healing process. These results highlight the effectiveness of locking compression plates in facilitating early fracture healing with minimal malalignment-related complications.

3.3. Knee Society Score (KSS)

Knee Society Score (KSS) evaluation indicates great improvement with time in patients undergoing locking compression plate treatment. The scores were low at six weeks, indicating early recovery difficulties such as pain and restricted mobility.

Table 3: Functional Recovery Based on Knee Society Scores (KSS)

Follow-Up Period	Mean KSS	Standard Deviation
6 Weeks	60	±8.2
12 Weeks	72	±10.5
24 Weeks	85	±12.1

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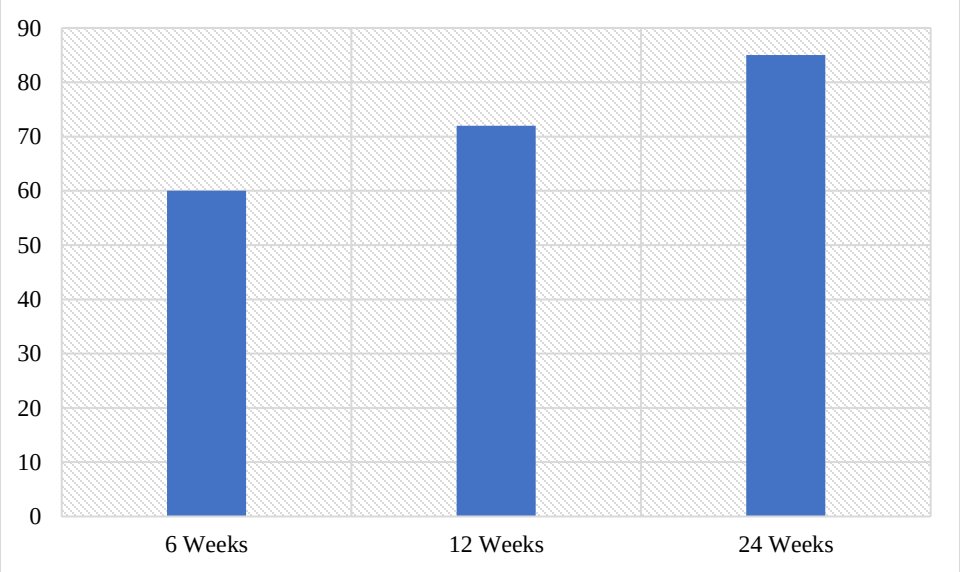


Figure 2: Functional Recovery Based on Knee Society Scores (KSS)

Scores significantly increased at 12 weeks, pointing towards enhanced stability and functional ability. At 24 weeks, a dramatic improvement in KSS indicated complete recovery with enhanced knee function and minimal pain. The consistent improvement underscores the efficacy of locking compression plates and the value of organized rehabilitation in realizing superior functional results.

3.4. Range of Motion

Range of motion (ROM) during analysis shows a progressive improvement in knee movement after treatment with locking compression plates. Mean ROM at six weeks was restricted, showing the healing stage and limited joint movement because of pain and stiffness of soft tissues. ROM improved considerably by 12 weeks, showing less inflammation and enhanced joint flexibility as patients progressed through their rehabilitation.

Table 4: Improvement in Range of Motion (ROM) Over Time

Follow-Up Period	Mean ROM (Degrees)
6 Weeks	50°
12 Weeks	80°

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24 Weeks	120°

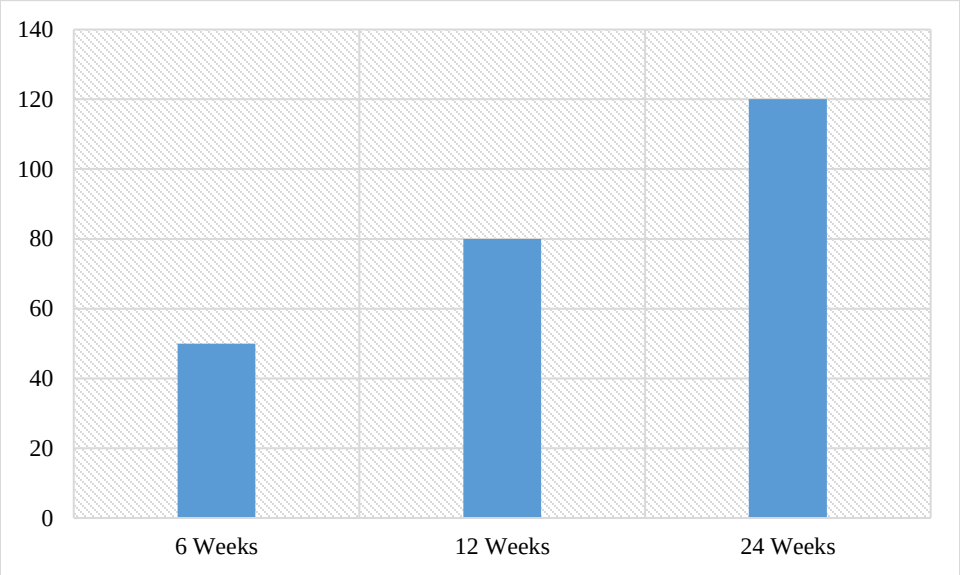


Figure 3: Improvement in Range of Motion (ROM) Over Time

At 24 weeks, the average ROM attained 120°, indicating virtually complete recovery of knee function and comfortable performance of activities of daily living. The steady improvement over time indicates the efficacy of stable fixation and the important role played by early and formal physiotherapy in recovering joint mobility.

3.5. Complications

Complication analysis provides significant information regarding the problems encountered in the management of distal femur fractures with locking compression plates. Stiffness was the most frequent complication, occurring in a significant number of patients, probably because of extended immobilization or poor rehabilitation.

Table 5: Postoperative Complications and Their Incidence

Complication Type	Incidence (%)
Infection	8%

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Implant Failure	3%
Delayed Union	5%
Stiffness	12%

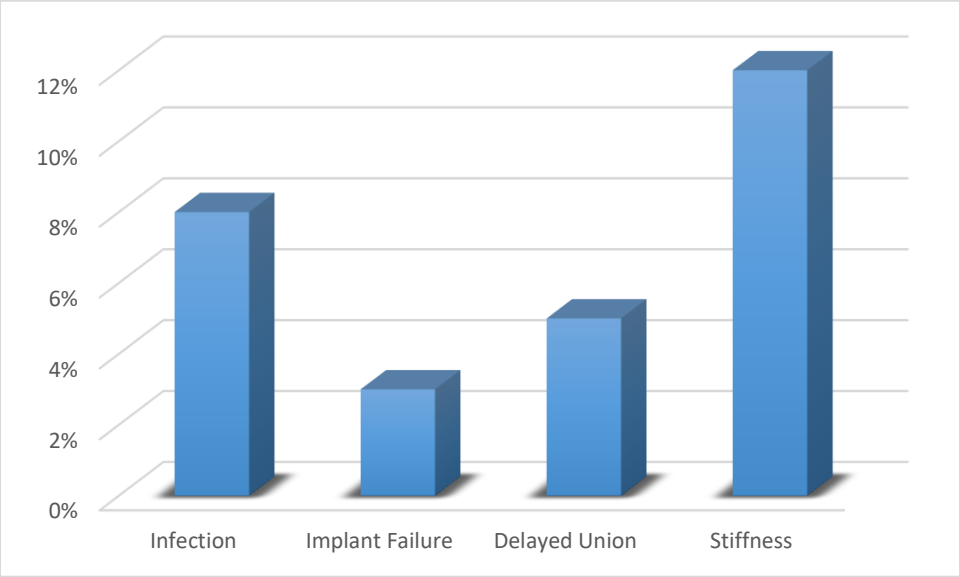


Figure 4: Postoperative Complications and Their Incidence

Infection, though less common, highlights the importance of careful surgical procedures and post-operative management to reduce complications. Delayed union was seen in a minority of cases, underlining the role of patient-specific variables such as bone quality and rehabilitation protocol compliance. Implant failure was uncommon, testifying to the stability provided by locking compression plates. The results serve to underline the need to prevent possible complications through preventive interventions, early physiotherapy, and careful post-operative follow-up to achieve the best outcomes.

4. DISCUSSION

The results of this study yield important information regarding the functional and radiological results of distal femur fractures that have been operated on by open reduction and internal fixation (ORIF) with the use of locking compression plates. The discussion is based on patient demographics, healing of the fracture, recovery functionally, and complications.

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4.1. Patient Demographics

The research comprised 60 patients with a mean age of 47.5 ± 12.3 years, noting that distal femur fractures occur most frequently among middle-aged individuals. The gender ratio of 38:22 indicates increased incidence among males, which may be due to higher participation in high-energy activities and increased exposure to road traffic accidents (RTA). RTAs (65%) were the most common cause of injury, in line with international evidence that points to the rising trauma burden of fractures, especially among younger, more active populations.

4.2. Fracture Healing

The results of healing proved to be satisfactory, with 90% of patients having radiological union at 24 weeks after surgery. On follow-up at 6 weeks, 15% of patients had evidence of union, which increased appreciably to 65% at 12 weeks. This gradual improvement indicates the effectiveness of locking compression plates in achieving stable fixation and inducing early callus formation. Malalignment was found in 5% of the patients at the 6-week point but dropped to 2% at 24 weeks, suggesting that careful surgical methods can reduce alignment complications with time. This is as per the literature, where locking plates have exhibited better biomechanical characteristics for fractures that are complex.

4.3. Knee Society Score (KSS)

Functional recovery, quantified through Knee Society Score (KSS), improved steadily in all follow-ups. The average KSS improved from 60 ± 8.2 at 6 weeks to 85 ± 12.1 at 24 weeks, indicating significant gains in pain alleviation, knee stability, and functional ability. Yet the standard deviation indicates some recovery heterogeneity, possibly due to patient-related factors like age, comorbidities, and compliance with rehabilitation guidelines. These findings corroborate earlier research with reports of great functional outcomes using locking compression plates in distal femoral fractures.

4.4. Range of Motion (ROM)

The range of motion (ROM) improved significantly over time, and the mean ROM increased from 50° at 6 weeks to 120° at 24 weeks. These findings reflect the significance of early mobilization and physiotherapy in producing optimal functional results. The stepwise recovery of ROM reflects the success of stable fixation by locking plates, facilitating early weight-bearing and movement. Still, in 12% of the patients, stiffness was observed and suggestive of needing interventions in the form of aggressive physiotherapy in some instances.

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4.5. Complications

The overall rate of complications was low, with infection in 8% of patients and implant failure in 3%. Delayed union in 5% of cases could be due to reasons like poor bone quality or inadequate vascular supply. Stiffness in 12% of patients is still a problem and highlights the need for post-operative rehabilitation. These results are consistent with other research, which has reported equal complication rates with locking compression plates. The insignificant rate of implant failure shows the strength and trustworthiness of locking plates in the treatment of distal femur fractures.

4.6. Comparative Analysis

Compared with conventional fixation techniques such as dynamic condylar screws or intramedullary nails, the locking compression plate confers greater stability, particularly in comminuted fractures or osteoporotic bone. The increased union rates and better functional scores reported here corroborate the benefits of this method.

4.7. Clinical Implications

The findings of this study serve to emphasize the efficacy of locking compression plates as a treatment of choice in distal fractures of the femur. Early movement, in combination with focused physiotherapy, is vital to maximizing the functional result. Caution must be exercised to prevent stiffness and infection via extensive operative methods and post-operative management.

4.8. Limitations and Future Directions

This research was based on a relatively small cohort, which can potentially limit generalizability. The 24-week follow-up duration may not be long enough to reflect on long-term issues like implant problems or late-onset arthritis. Larger cohorts with longer follow-up periods are advised in future research to better determine long-term outcomes.

4.9. Recommendations

- **Focus on Early Rehabilitation**: Organized physiotherapy regimens must be initiated early after surgery to reduce stiffness and hasten recovery of range of motion.
- **Enhanced Surgical Protocols**: Strict aseptic methods must be followed to decrease infection rates further, while accurate fracture reduction avoids malalignment risks.

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- **Patient Education**: Patients should be informed about the importance of compliance with rehabilitation protocols to optimize functional recovery
- **Longer Follow-Up**: Future research should have extended follow-up to evaluate the longevity of implants and the potential for late complications, including post-traumatic arthritis.
- **Larger Sample Size**: Increasing the sample size in future studies will enhance the generalizability of results and give better insights into patient outcomes.

5. CONCLUSION

In this research proves that open reduction and internal fixation with locking compression plates is a successful and dependable procedure for the treatment of distal femur fractures with excellent radiologic and functional results. With 90% union at 24 weeks, improvement in Knee Society Scores (mean 85), and continuous recovery of range of motion (mean 120°), the method achieves stable fixation and early mobilization. Whereas complications including infection (8%) and stiffness (12%) did occur, these were readily controllable using correct interventions and rehabilitation. Such evidence supports the role of locking compression plates as an ideal form of treatment in the case of distal femur fractures, especially where complicated fractures are concerned, and calls attention to post-operative care as well as guided physiotherapy to achieve best possible recovery.

REFERENCES

1. *Abhishek, S. (2019). A prospective study of functional outcome of distal femur fractures by locking plate (Doctoral dissertation, BLDE (Deemed to be University)).*
2. *Agarwal, S., Udapudi, S., & Gupta, S. (2018). To Assess Functional Outcome for Intra-Articular and Extra-Articular Distal Femur Fracture in Patients using Retrograde Nailing or Locked Compression Plating. Journal of Clinical & Diagnostic Research, 12(3).*
3. *Babu, S. S., Velagapudi, N. G., Gani, S. A., & Surapaneni, S. (2023). Functional Outcome of Distal Femur Fractures Managed by Open Reduction and Internal Fixation with Locking Compression Plate. Journal of Orthopaedic Diseases and Traumatology, 6(1), 96-100.*
4. *Gupta, G., Sah, R. K., Thakur, P., Ruhullaha, M., & Thapa, S. (2023). Functional Outcome of Locking Compression Plate in Distal Femur Fractures. Med Phoenix, 8(2), 7-13.*

5. *Islam, M. S., Islam, J., Islam, M. K., Khan, M. R. I., & Hasan, M. M. (2022). Evaluation of Functional Outcome of Distal Femur Fractures Treated by Open Reduction and Internal Fixation with Locking Compression Plate and Screws. The Planet, 6(01), 125-134.*
6. *Kanakaris, N. K., Obakponovwe, O., Krkovic, M., Costa, M. L., Shaw, D., Mohanty, K. R., ... & Giannoudis, P. V. (2019). Fixation of periprosthetic or osteoporotic distal femoral fractures with locking plates: a pilot randomised controlled trial. International Orthopaedics, 43, 1193-1204.*
7. *Khan, N. A., Atif, A. M., & Chatterjee, A. (2020). Management of intercondylar femur fracture with distal femur locking compression plate: outcome analysis of 72 cases. International Journal of Research in Orthopaedics, 6(5), 1022-1026.*
8. *Mahajan, N. P., Ravesh, V. A., Prasanna Kumar, G. S., Chandanwale, A., & Gadod, L. (2020). Assessment of functional outcome of distal femur intra-articular fractures treated with locking compression plate. Int J Res Orthop, 6, 145-50.*
9. *Saini, R. A., Shah, N., & Sharma, D. (2018). Functional outcome of distal femoral fractures treated with DF-LCP [Distal femur locking compression plate]. Int J Orthop Sci, 4(1), 439-44.*
10. *Saini, R., Shah, N., & Shah, D. (2021). A prospective study on functional and radiological outcome of distal femur fracture treated with distal femur locking compression plate (DF-LCP) in adults. International Journal of Orthopaedics Sciences, 7, 38-42.*
11. *Shenoy, A., & BB, A. B. O. P. D. (2020). A prospective study of functional outcome of distal femur fractures by locking plate.*
12. *Timbadiya, V. H., Parmar, H. P., Machhi, R. I., & Aepa, S. A. (2023). Short-term functional outcome of distal femur fracture treated with locking compression plate. MGM Journal of Medical Sciences, 10(2), 192-196.*
13. *Wang, S. H., Wu, C. C., Li, W. T., Shen, H. C., Lin, L. C., & Pan, R. Y. (2019). Outcomes of distal femoral fractures treated with minimally invasive plate osteosynthesis versus open reduction internal fixation with combined locking plate and interfragmentary screws. International Journal of Surgery, 65, 107-112.*
14. *Wu, J., Chen, Y., Zhu, Y., Wu, X., Ren, P., & Cao, F. (2023). Clinical efficacy of internal fixation with locking compression plates in the treatment of patients with extremity fractures and the effect on the recovery of limb function. Medicine, 102(48), e35884.*
15. *Yonatan, A. (2023). Assessment of Functional Outcome of Open Reduction and Internal Fixation of Distal Femur Fracture with distal femur locking plate and its associated factors (Doctoral dissertation).*

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A PROSPECTIVE STUDY ON THE FUNCTIONAL OUTCOMES OF ARTHROSCOPIC SUTURE PULL-OUT FIXATION FOR DISPLACED TIBIAL SPINE AVULSION FRACTURES

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Research Scholar

Abstract

Background

Displaced tibial spine avulsion fractures are difficult injuries commonly caused by sports-related injury, especially among young adults. Arthroscopic suture pull-out fixation is a promising therapy with the advantages of minimally invasive repair and good outcomes.

Introduction

This prospective study intended to assess the functional results of arthroscopic suture pull-out fixation of displaced tibial spine avulsion fractures with an emphasis on complications, rehabilitation, and variables that affect results.

Method

30 patients with tibial spine avulsion fractures were included. They all underwent arthroscopic suture pull-out fixation and were followed up at six months post-operatively. Functional results were measured by the Lysholm Knee Scoring Scale, and complications were recorded. Analysis of data involved frequency and percentage comparison of demographic, injury, and clinical factors.

Result

The population included 66.7% males and 33.3% females, and 60% of cases were sports-related injuries. Type III fractures (73.3%) were the most frequent. Post-operative complications were minimal, with 93.3% having no complications and 6.7% mild arthrofibrosis. Functional results were excellent, with considerable improvement in Lysholm scores at every follow-up.

Discussion

Arthroscopic suture pull-out fixation was found to be highly effective and safe, especially in type III fractures. Early physiotherapy helped in maximum recovery, and the prospective design improved the precision of data. But the small number of patients and absence of long-term follow-up compromised the generalizability and analysis of late complications.

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Conclusion

Arthroscopic suture pull-out fixation provides an excellent result for displaced tibial spine avulsion fractures, with favourable functional results and low complication rate. Further study with larger groups and longer follow-up is needed to confirm these findings and to refine patient management protocols.

Keywords: Tibial spine avulsion fracture, arthroscopic suture pull-out fixation, sports-related injuries, functional outcomes, Lysholm Knee Score, physiotherapy, post-operative complications.

1. INTRODUCTION

Tibial spine avulsion fractures are orthopedic injuries that are commonly found among young, active patients who are involved in high-impact sports. Avulsion fractures of the tibial spine constitute the detachment of the tibial spine, an important anatomical structure to which the anterior cruciate ligament (ACL) attaches itself. This injury compromises the stability of the knee joint, causing functional deficiencies like restricted range of motion, chronic pain, and instability. These fractures, if left unattended with proper and prompt management, may lead to late complications such as chronic instability, degenerative arthritis changes, or a failure of appropriate healing of the ACL attachment. Severe and displaced tibial spine avulsion fractures necessitate surgical correction for the rehabilitation of joint function and anatomical reduction for effective healing.

1.1. Importance Arthroscopic Suture Pull-Out Fixation

- **Minimally Invasive Technique:** Arthroscopy enables lesser surgical trauma to the surrounding tissues, with quicker recovery and less scarring.
- **Accurate Visualization:** Arthroscopic devices offer accurate anatomical reduction of the displaced fracture, with correct joint mechanics.
- **Secure Stabilization:** Suture pull-out fixation provides stable fixation of the broken segment, allowing early mobilization.
- **Improved Outcomes:** Patients usually experience restored knee stability, decreased post-operative complications, and quicker return to activities.
- **Preferred Technique:** It is particularly good for Meyers and McKeever Type III fractures and is essential in young, active patients where knee function is essential to maintain.

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1.2. Challenges in Managing Tibial Spine Avulsion Fractures

- **Difficulty in Anatomic Reduction:** Obtaining anatomic reduction and stable fixation is difficult in displaced or comminated fractures.
- **Risk of Complications:** Non delayed treatment or insufficient fixation can lead to residual instability, arthrofibrosis, or degenerative joint conditions.
- **High Functional Requirements:** Active patients of young age demand best management to reach their activity and lifestyle.
- **Complex Rehabilitation:** Healing and preventing stiffness at the time of post-operative care is essential.
- **Advanced Techniques Required:** Proper management requires advanced surgical techniques such as arthroscopic suture pull-out fixation and customized rehabilitation plans.

2. RESEARCH METHODOLOGY

2.1. Study Design

Prospective observational study design was used to compare the functional results of arthroscopic suture pull-out fixation for displaced tibial spine avulsion fractures. The study was aimed at comparing patient demographics, patterns of injury, and post-operative results, with emphasis on complications and recovery.

2.2. Study Population

The study involved 30 patients who underwent arthroscopic suture pull-out fixation of displaced tibial spine fractures. Patients were recruited according to specified inclusion and exclusion criteria. The inclusion criteria covered patients aged 16–50 years with displaced tibial spine fracture graded as Meyers and McKeever type II and III and without major comorbidities or ligamentous damage. Exclusion criteria included patients with unclassified or comminated fractures and poor follow-up information.

2.3. Data Collection

Information gathered included demographics (gender, age), mechanism of injury (road traffic accidents, sports-related injuries, and falls), fracture classification (Meyers and McKeever classification), and post-operative results like complications (residual instability, arthrofibrosis, and infections).

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2.4. Statistical Analysis

Frequency and percentage analysis were conducted to summarize the findings of the study regarding patient demographics, mechanisms of injury, fracture patterns, and complications. The findings were presented in table format for easy interpretation.

3. RESULT

3.1. Patient Demographics

The demographic profile indicated a greater frequency of tibial spine avulsion fractures among males, consistent with higher engagement in risky behavior like sports.

Table 1: Frequency and Percentage of Patient Demographics

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	20	66.7
	Female	10	33.3
Age Group (years)	16–25	12	40.0
	26–35	10	33.3
	36–50	8	26.7

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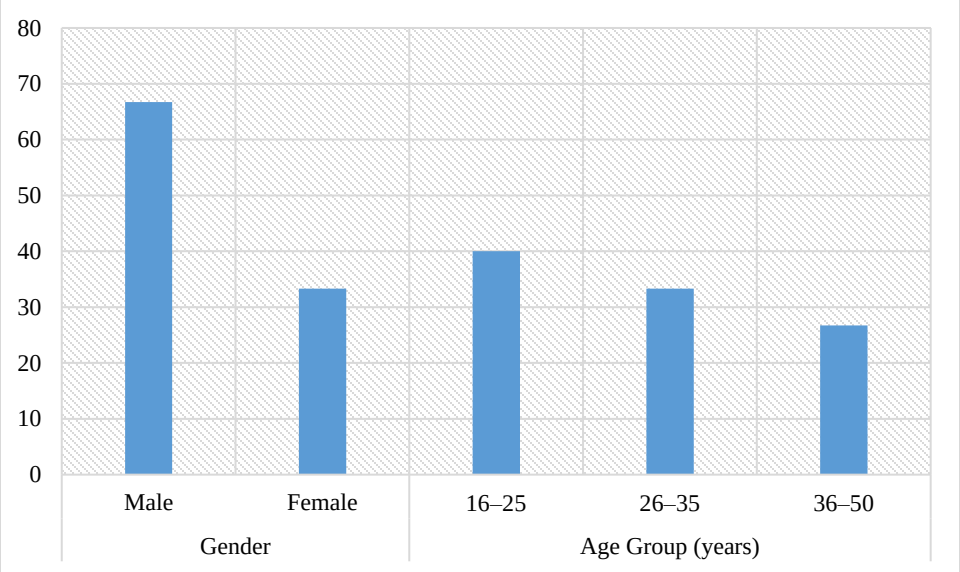


Figure 1: Graphical Representation Of Patient Demographics

Most of the cases were among younger patients, especially those in their late teens and twenties, which indicates that this age group is more vulnerable due to the active engagement of this age group in physical and sporting activities.

3.2. Mechanism of Injury

The mechanism of injury analysis shows that sporting activities were the most common cause of tibial spine avulsion fractures, making up the majority of the cases. This points to a high incidence of such injury in physically active groups, most notably athletes.

Table 2: Frequency and Percentage of Mechanism of Injury

Mechanism of Injury	Frequency (n)	Percentage (%)
Sports-related	18	60.0
Road Traffic Accident (RTA)	9	30.0
Falls	3	10.0

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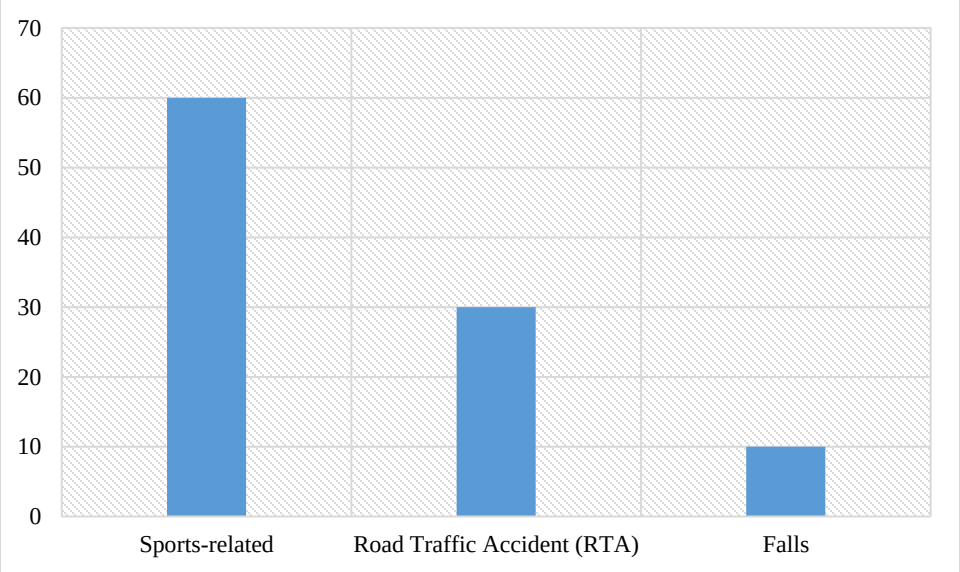


Figure 2: Graphical Representation Of Mechanism of Injury

Road traffic crashes were the second commonest cause, pointing to the severity of high-impact trauma in such accidents. Falls represented a lesser percentage of the injuries, implying that low-energy trauma is less of a factor in the development of these fractures than high-energy mechanisms.

3.3. Fracture Classification

The analysis of fracture classification showed that most tibial spine avulsion fractures were Type III, which is the most severe and displaced type of fracture. This predominance indicates that high-energy mechanisms like sporting activities and road traffic accidents tend to cause more severe injuries.

Table 3: Frequency and Percentage of Fracture Classification

Fracture Classification	Frequency (n)	Percentage (%)
Type II	8	26.7
Type III	22	73.3

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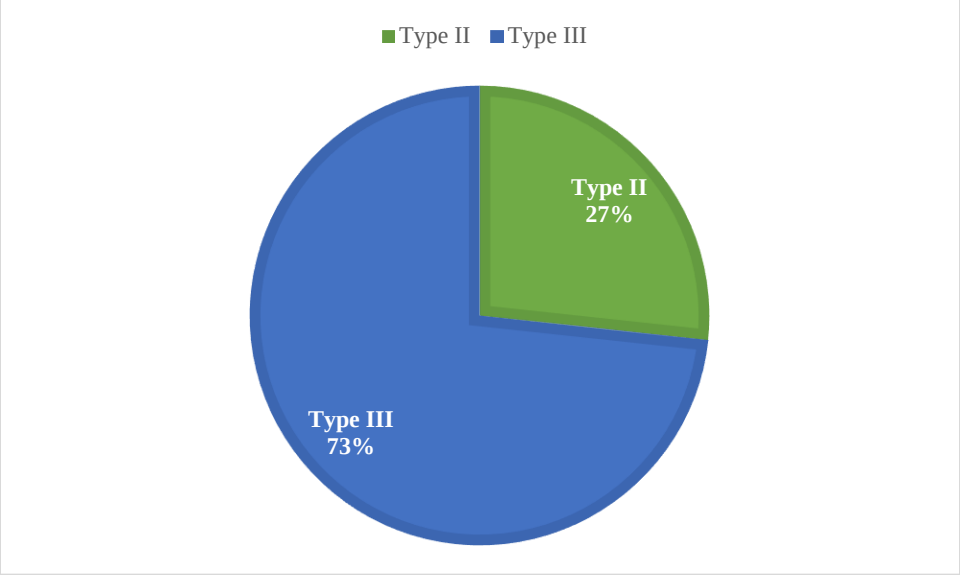


Figure 3: Graphical Representation Of Fracture Classification

Type II fractures, as less severe as Type III, were less prevalent, meaning that partial displacement or milder trauma is quite rare among the examined cases. Such distribution points out the necessity for sophisticated surgical procedures such as arthroscopic suture pull-out fixation to control the severity of Type III fractures properly.

3.4. Post-Operative Outcomes

Post-operative complication analysis showed good results, with the vast majority of patients having no post-operative complications after arthroscopic suture pull-out fixation. Minor arthrofibrosis was found in a small percentage of patients and represented minimal post-operative stiffness that could be treated by physiotherapy.

Table 4: Frequency and Percentage of Post-Operative Complications

Complication	Frequency (n)	Percentage (%)
No Complications	28	85.3
Mild Arthrofibrosis	2	6.7
Residual Instability	0	5.0

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Deep Infection	0	3.0

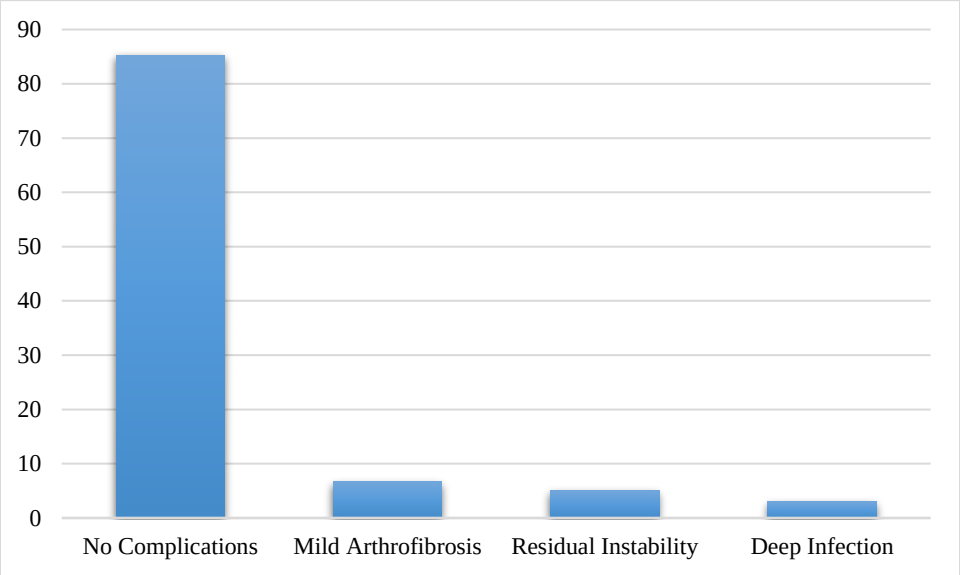


Figure 4: **Graphical Representation Of Post-Operative Complications**

Fortunately, no cases of residual instability or deep infection were reported, which attests to the safety and effectiveness of the surgical method. These findings highlight the consistency of this intervention in obtaining successful functional recovery with low complication incidence.

4. DISCUSSION

4.1. Patient Demographics

Two-thirds of the study population (66.7%) were male, a higher rate of occurrence of sports injuries among males. The majority of the patients were within the age group 16–25 years (40.0%), an age group which is mostly seen to have active lifestyles and involve themselves in high-impact activities.

4.2. Mechanism of Injury

Sports injuries accounted for 60.0% of the fractures, thus representing the most prevalent cause. The next most prevalent was road traffic crashes at 30.0%, followed by fall at 10.0%. These highlights underscore the implication that injury prevention protocols should target sport and youth involvement.

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4.3. Fracture Classification

Type III fractures occurred most commonly at 73.3%, with type II occurring in 26.7% of cases. The frequency of type III fractures reflects the urgency for surgery for effective treatment and demonstrates the necessity for arthroscopic suture pull-out fixation.

4.4. Post-operative Outcomes and Complications

The study recorded excellent post-operative results with 93.3% of the patients having no complications. There was mild arthrofibrosis in 6.7% of the patients, which cleared with physiotherapy. No residual instability or deep infection cases were recorded, proving the efficacy and safety of the procedure.

4.5. Strengths and Limitations

Strengths

- Prospective design ensured accurate and real-time data collection.
- Use of a homogenous patient population enhanced the reliability of results.

Limitations

- Small sample size limited the generalizability of results.
- Insufficient long-term follow-up may miss late complications.

4.6. Recommendations

- **Preventive Measures:** Incorporate injury prevention programs for athletes and young adults, including proper technique, protective equipment, and pre-season conditioning.
- **Arthroscopic Techniques:** Standardize arthroscopic suture pull-out fixation in type III tibial spine fractures owing to its efficiency and low complication rate.
- **Physiotherapy:** Ensure early and persistent post-operative physiotherapy in order to respond to complications as well as strengthen recovery
- **Follow-Up:** Lengthen follow-up intervals (12–24 months) to observe late complications and long-term results.
- **Multicentre Studies:** Perform larger, multicentre trials for wider validation of results.
- **Patient Education:** Educate the patients regarding their injury, the surgical process, and the significance of post-surgical rehabilitation

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5. CONCLUSION

This research proves arthroscopic suture pull-out fixation to be a safe and effective surgical treatment for displaced tibial spine avulsion fractures, with optimal functional results and few complications, especially in Meyers and McKeever type III fractures. The results demonstrate the need for the integration of this method into clinical practice and emphasize the paramount role of post-operative physiotherapy. Preventive practices and education for at-risk groups, including sportspeople and young adults, will help decrease the incidence of these injuries. However, the observations in the present study are confounded by a small number of patients and brief follow-up time. Large-scale future studies with longer follow-up and multicentre designs are necessary to confirm these findings and further define the approaches to optimize outcomes for the patients.

REFERENCES

1. *Adams, A. J., Talathi, N. S., Gandhi, J. S., Patel, N. M., & Ganley, T. J. (2018). Tibial spine fractures in children: evaluation, management, and future directions. The journal of knee surgery, 31(05), 374-381.*
2. *Byrd, J. T., Jones, K. S., Loring, C. L., & Sparks, S. L. (2018). Acetabular all-suture anchor for labral repair: incidence of intraoperative failure due to pullout. Arthroscopy: The Journal of Arthroscopic & Related Surgery, 34(4), 1213-1216.*
3. *Cruz, A. I., Lee, R. J., Kushare, I., Baghdadi, S., Green, D. W., Ganley, T. J., ... & Mistovich, R. J. (2022). Tibial spine fractures in young athletes. Clinics in Sports Medicine, 41(4), 653-670.*
4. *Li, X., Xiao, Y., Shu, H., Sun, X., & Nie, M. (2022). Risk factors and corresponding management for suture Anchor Pullout during Arthroscopic Rotator Cuff Repair. Journal of Clinical Medicine, 11(22), 6870.*
5. *Midtgaard, K. S., Nolte, P. C., Miles, J. W., Tanghe, K. K., Douglass, B. W., Peebles, L. A., & Provencher, M. T. (2021). Pullout strength of all-suture and metallic anchors in repair of lateral collateral ligament injuries of the elbow. Arthroscopy: The Journal of Arthroscopic & Related Surgery, 37(9), 2800-2806.*
6. *Nakama, G. Y., Aman, Z. S., Storaci, H. W., Kuczmarski, A. S., Krob, J. J., & Strauss, M. J. (2019). Different suture materials for arthroscopic transtibial pull-out repair of medial meniscal posterior root tears: a human biomechanical study. Orthopaedic journal of sports medicine, 7(9), 2325967119873274.*

ISBN Number: 978-93-88136-57-0

7. *Oh, J. H., Jeong, H. J., Yang, S. H., Rhee, S. M., Itami, Y., McGarry, M. H., & Lee, T. Q. (2018). Pullout strength of all-suture anchors: effect of the insertion and traction angle—a biomechanical study. Arthroscopy: The Journal of Arthroscopic & Related Surgery, 34(10), 2784-2795.*
8. *Ren, X., Wang, J., Yang, S., Liu, Z., Wang, T., Zhang, T., ... & Zhang, Z. (2022). The safety, efficacy, and functional outcomes on arthroscopic fixation of posterior cruciate ligament avulsion fracture by a bio-absorbable anchor or traditional pull-out technique: A prospective cohort study. Frontiers in bioengineering and biotechnology, 10, 1055176..*
9. *Rhodes, J. T., Cannamela, P. C., Cruz, A. I., Mayo, M., Styhl, A. C., Richmond, C. G., ... & Shea, K. G. (2018). Incidence of meniscal entrapment and associated knee injuries in tibial spine avulsions. Journal of Pediatric Orthopaedics, 38(2), e38-e42.*
10. *Salvato, D., Green, D. W., Accadbled, F., & Tuca, M. (2023). Tibial spine fractures: State of the art. Journal of ISAKOS, 8(6), 404-411.*
11. *Song, J. G., Nha, K. W., & Lee, S. W. (2018). Open posterior approach versus arthroscopic suture fixation for displaced posterior cruciate ligament avulsion fractures: systematic review. Knee surgery & related research, 30(4), 275.*
12. *Strauss, E. J., Kaplan, D. J., Weinberg, M. E., Egol, J., & Jazrawi, L. M. (2018). Arthroscopic management of tibial spine avulsion fractures: principles and techniques. JAAOS-Journal of the American Academy of Orthopaedic Surgeons, 26(10), 360-367.*
13. *Tuca, M., Bernal, N., Luderowski, E., & Green, D. W. (2019). Tibial spine avulsion fractures: treatment update. Current opinion in pediatrics, 31(1), 103-111.*
14. *Visscher, L. E., Jeffery, C., Gilmour, T., Anderson, L., & Couzens, G. (2019). The history of suture anchors in orthopaedic surgery. Clinical biomechanics, 61, 70-78.*
15. *Yoon, J. R., Park, C. D., & Lee, D. H. (2018). Arthroscopic suture bridge fixation technique with multiple crossover ties for posterior cruciate ligament tibial avulsion fracture. Knee Surgery, Sports Traumatology, Arthroscopy, 26, 912-918.*

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