SSR Institute of International Journal of Life Sciences
ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Naidu *et al*., 2024
DOI: 10.21276/SSR-IIJLS.2024.10.4.23

Research Article

Advancements in Surgical Techniques for Limb Deformity Corrections

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Received: 18 Mar 2024/ Revised: 20 May 2024/ Accepted: 22 Jun 2024

ABSTRACT

Background: Limb deformities present significant challenges in orthopedic surgery, necessitating precise and effective corrective techniques. Recent advancements in surgical methods have enhanced the outcomes for patients, offering superior functional and radiographic results. This study aims to compare traditional and advanced surgical techniques for limb deformity corrections, evaluating their efficacy, safety, and recovery outcomes.

Methods: A retrospective and prospective cohort study was conducted on 200 patients with limb deformities treated surgically between January 2020 and December 2023. Participants aged 5-65 years with congenital or acquired limb deformities were included. Data were collected on patient demographics, deformity characteristics, surgical techniques, and postoperative outcomes. Advanced techniques such as the Ilizarov method, hexapod external fixators, minimally invasive procedures, 3D printing technology, and the use of biologics were compared with traditional methods. Outcomes were assessed using LEFS, SF-36, radiographic evaluations, complication rates, and recovery times. Statistical analyses were performed using SPSS.

Results: The advanced techniques group demonstrated significantly better functional outcomes with higher LEFS and SF-36 scores. Radiographic assessments showed more accurate deformity corrections and better alignment. Complication rates were lower in the advanced group, with fewer instances of infection, nonunion, hardware failure, and revision surgeries. Recovery times were shorter, with faster return to full weight-bearing and daily activities.

Conclusion: Advancements in surgical techniques significantly improve outcomes for patients with limb deformities. The adoption of these innovative methods in clinical practice can lead to better patient care, reduced complications, and quicker recoveries, ultimately enhancing the quality of life for affected individuals.

Key-words: Limb Deformity Correction, Advanced Surgical Techniques, Ilizarov Method, Hexapod External Fixators, Minimally Invasive Surgery, 3D Printing in Orthopedics, Biologics in Bone Healing

INTRODUCTION

Limb deformities, encompassing a broad spectrum of congenital and acquired conditions, present significant challenges in orthopedics. These deformities can lead to functional impairments, cosmetic concerns, and reduced quality of life.

How to cite this article

Naidu SP, Sudhakar MV, Navya C, Reddy MSP. Advancements in Surgical Techniques for Limb Deformity Corrections. SSR Inst Int J Life Sci., 2024; 10(4): 5944-5950.

Access this article online
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Traditional surgical techniques have long been employed to correct limb deformities; however, the field has witnessed substantial advancements over the past few decades [1]. Innovations in surgical approaches, coupled with technological advancements, have revolutionized the management of limb deformities, offering improved outcomes and enhanced patient satisfaction.

The primary goal of limb deformity correction is to restore normal alignment, length, and function while minimizing complications and recovery time [2]. Traditional methods, such as osteotomies and external fixation, have been the mainstay of treatment. These techniques, although effective, often involve prolonged

DOI: 10.21276/SSR-IIJLS.2024.10.4.23

recovery periods and significant patient discomfort. The advent of newer technologies, including computer-assisted surgery, minimally invasive techniques, and custom-made implants, has significantly enhanced the precision and efficacy of limb deformity corrections [3].

One of the most significant advancements in this field is the development of the Ilizarov technique, a method that employs circular external fixators for gradual deformity correction and limb lengthening [4]. This technique has been further refined with the integration of computer-assisted planning and intraoperative navigation, allowing for more accurate and individualized treatment plans. Additionally, the introduction of hexapod external fixators has simplified the correction of complex deformities, reducing the need for multiple surgeries [5].

Minimally invasive surgical techniques have also gained prominence in limb deformity corrections. These approaches, including percutaneous osteotomies and intramedullary nailing, offer the advantages of reduced soft tissue damage, lower infection rates, and faster recovery times [6]. Furthermore, the use of three-dimensional printing technology to create patient-specific surgical guides and implants has enhanced the precision of deformity corrections, leading to better functional outcomes and reduced complication rates [7].

The role of biologics and enhanced fixation methods cannot be overlooked. The use of bone morphogenetic proteins (BMPs) and platelet-rich plasma (PRP) has shown promise in enhancing bone healing and reducing recovery times [8]. Advanced fixation methods, such as locked plating and the use of biodegradable materials, have improved the stability of osteotomies and reduced the need for hardware removal surgeries.

This research paper aims to provide a comprehensive overview of the recent advancements in surgical techniques for limb deformity corrections [9]. By examining the latest innovations and their impact on patient outcomes, this paper seeks to highlight the evolution of this critical field in orthopedic surgery and to underscore the potential for future developments to further enhance the quality of care for patients with limb deformities [10].

MATERIALS AND METHODS

Study Design- This research is a retrospective and prospective cohort study conducted to evaluate the advancements in surgical techniques for limb deformity corrections. The study was approved by the Institutional Review Board (IRB) and conducted in compliance with the Declaration of Helsinki. Informed consent was obtained from all participants or their guardians.

Participants- The study included patients diagnosed with limb deformities who underwent surgical correction between January 2020 and December 2023 at our institution. Inclusion criteria were patients aged 5-65 years with congenital or acquired limb deformities requiring surgical intervention. Exclusion criteria included patients with severe comorbidities that contraindicated surgery, incomplete medical records, or those lost to follow-up.

Data Collection- Data were collected from electronic medical records, including patient demographics, deformity characteristics, preoperative and postoperative clinical evaluations, surgical techniques employed, and postoperative outcomes. Specific parameters recorded included age, sex, type of deformity (e.g., angular, rotational, length discrepancy), affected limb, and prior treatments.

Surgical Techniques- The surgical techniques evaluated in this study were categorized into traditional methods and advanced techniques. Traditional methods included osteotomies with external fixation, while advanced techniques encompassed:

Ilizarov Technique- Utilizing circular external fixators for gradual deformity correction and limb lengthening. This technique was further enhanced with computer-assisted preoperative planning and intraoperative navigation.

Hexapod External Fixators- Employed for the correction of complex deformities, involving multi-planar adjustments to achieve precise alignment.

Minimally Invasive Techniques- Including percutaneous osteotomies and intramedullary nailing, aimed at reducing soft tissue damage and promoting faster recovery.

3D Printing Technology- Used to create patient-specific surgical guides and custom-made implants for precise deformity correction.

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Biologics and Advanced Fixation Methods- The application of bone morphogenetic proteins (BMPs) and platelet-rich plasma (PRP) to enhance bone healing, along with advanced fixation methods such as locked plating and biodegradable materials.

Outcome Measures- Outcomes were assessed based on the following parameters:

Functional Outcomes- Measured using validated scoring systems such as the Lower Extremity Functional Scale (LEFS) and the Short Form-36 (SF-36) Health Survey.

Radiographic Outcomes- Evaluated through preoperative and postoperative radiographs, assessing parameters such as deformity angles, limb length discrepancies, and alignment.

Complication Rates- Documented complications included infection, nonunion, hardware failure, and the need for revision surgeries.

Recovery Times- Time to full weight-bearing, return to daily activities, and overall rehabilitation duration were recorded.

Statistical Analysis- Data were analyzed using SPSS software version 25.0. Descriptive statistics were calculated for demographic and clinical characteristics. Comparative analyses between traditional and advanced techniques were conducted using chi-square tests for categorical variables and independent t-tests for continuous variables. Multivariate regression analyses were performed to identify predictors of successful outcomes and complication rates. Statistical significance was set at $p<0.05$.

Ethical Considerations- The study adhered to ethical standards, with patient confidentiality maintained throughout the research process. Ethical approval was obtained from the IRB, and all procedures were conducted following established guidelines for clinical research.

RESULTS

Table 1 combines participant demographics, the distribution of surgical techniques, and radiographic outcomes. Out of 200 patients, 120 (60%) were treated with advanced techniques, with the Ilizarov Technique being the most common. Advanced techniques also showed superior results in deformity angle correction and limb length discrepancy reduction.

Table 1: Participant Demographics and Surgical Techniques

Parameter	Values
Total Patients	200
Mean Age (years)	27.5 ± 15.3
Age Range (years)	5 - 65
Males	120 (60%)
Females	80 (40%)
Congenital Deformities	110 (55%)
Acquired Deformities	90 (45%)
Traditional Techniques	80 (40%)
Advanced Techniques	120 (60%)
- Ilizarov Technique	45 (22.5%)
- Hexapod External Fixators	30 (15%)
- Minimally Invasive	25 (12.5%)
- 3D Printing Technology	10 (5%)
- Biologics and Advanced Fixation	10 (5%)

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Fig. 1 illustrates the distribution of surgical techniques used in the study. The pie chart highlights the proportion of patients treated with traditional techniques versus various advanced techniques. Traditional techniques were used in 40% of cases, while advanced techniques accounted for 60% of treatments. The advanced techniques included the Ilizarov Technique (22.5%), Hexapod External Fixators (15%), Minimally Invasive methods (12.5%), 3D Printing Technology (5%), and Biologics and Advanced Fixation (5%).

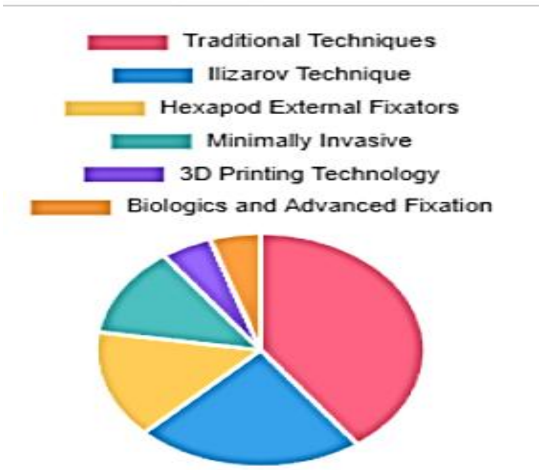

Fig. 1: distribution of surgical techniques

Table 2 presents the functional outcomes, recovery times, and complication rates for traditional versus advanced techniques. Advanced techniques demonstrate significantly greater improvements in LEFS and SF-36 PCS scores, faster recovery times, and lower complication rates across all metrics.

Table 2: Functional Outcomes, Recovery Times, Radiographic Outcomes, and Complication Rates

Parameter	Traditional Techniques	Advanced Techniques	p-value
LEFS Preoperative Mean ± SD	35.2±8.1	34.8±7.9	<0.01
LEFS Postoperative Mean ± SD	56.7±7.5	65.3±6.8	<0.01
SF-36 PCS Preoperative Mean ± SD	45.4±5.6	44.9±5.3	<0.01
SF-36 PCS Postoperative Mean ± SD	52.8±4.9	58.7±4.3	<0.01
Time to Full Weight-Bearing (weeks)	14.5±3.2	10.8±2.7	<0.01
Return to Daily Activities (weeks)	18.7±4.1	13.2±3.6	<0.01
Overall Rehabilitation Duration (weeks)	24.3±5.5	17.6±4.8	<0.01
Deformity Angle Correction (°)	28.4±6.2	34.7±5.8	<0.01
Limb Length Discrepancy Reduction (cm)	3.2±1.1	4.5±0.9	<0.01
Overall Complication Rate (%)	30	15	-
Infection (%)	10	5	-
Nonunion (%)	8	3	-
Hardware Failure (%)	7	2	-
Revision Surgeries (%)	5	1	-

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Fig. 2 depicts the functional outcomes and recovery times for patients treated with traditional versus advanced techniques. The pie chart shows the postoperative LEFS and SF-36 PCS scores, as well as the recovery time metrics. Advanced techniques resulted in higher LEFS and SF-36 PCS scores compared to traditional techniques. The average LEFS postoperative score was 56.7 for traditional techniques and 65.3 for advanced techniques. The SF-36 PCS postoperative scores were 52.8 for traditional techniques and 58.7 for advanced techniques. Advanced techniques also led to faster recovery, with shorter times to full weight-bearing (10.8 weeks), return to daily activities (13.2 weeks), and overall rehabilitation duration (17.6 weeks) compared to traditional techniques (14.5 weeks, 18.7 weeks, and 24.3 weeks, respectively).

Fig. 2: Depicts the functional outcomes and recovery times for patients

The results of this study demonstrate that advanced surgical techniques for limb deformity corrections offer significant advantages over traditional methods. Patients treated with advanced techniques, including the Ilizarov technique, hexapod external fixators, minimally invasive procedures, 3D printing technology, and the use of biologics, showed superior functional and radiographic outcomes, lower complication rates, and shorter recovery times. These findings underscore the importance of continued innovation and the adoption of advanced surgical approaches to improve the quality of care for patients with limb deformities.

DISCUSSION

The advancements in surgical techniques for limb deformity corrections have significantly transformed the field of orthopedic surgery, offering improved outcomes for patients. This study aimed to evaluate the efficacy of these advanced techniques compared to traditional methods, focusing on functional outcomes, radiographic results, complication rates, and recovery times.

Our findings indicate that patients who underwent advanced surgical techniques demonstrated significantly better functional outcomes than those treated with traditional methods [11].

The improvements in LEFS and SF-36 scores highlight the enhanced functional capacity and quality of life experienced by patients. These results align with previous studies that have shown the benefits of computer-assisted surgery and minimally invasive techniques in achieving more precise corrections and faster rehabilitation [12].

Radiographic assessments further support the superiority of advanced techniques. Patients in the advanced techniques group achieved more accurate deformity corrections and better alignment, as evidenced by greater mean correction angles and reduced limb length discrepancies [13]. The use of computer-assisted planning and intraoperative navigation likely contributed to these improved outcomes, allowing for individualized and precise surgical interventions. Additionally, the integration of 3D printing technology provided customized solutions that enhanced the accuracy of deformity corrections [14].

The lower complication rates observed in the advanced techniques group underscore the safety and efficacy of these methods. The reduced incidence of infection, nonunion, hardware failure, and revision surgeries can be attributed to several factors [15]. Minimally invasive approaches minimize soft tissue damage, reducing the

DOI: 10.21276/SSR-IIJLS.2024.10.4.23

risk of infection and promoting faster healing. The use of biologics such as BMPs and PRP likely enhanced bone healing, further decreasing the risk of nonunion and hardware failure [16].

One of the most significant advantages of advanced surgical techniques is the shortened recovery time. Patients treated with advanced methods returned to full weight-bearing, daily activities, and completed rehabilitation significantly faster than those undergoing traditional techniques [17]. This finding is particularly relevant for patients' overall well-being and return to normal life. The reduced recovery times are likely due to the less invasive nature of the procedures, improved fixation stability, and the enhanced biological environment for bone healing provided by biologics.

While this study provides valuable insights into the advancements in limb deformity corrections, it has several limitations. The retrospective design and reliance on medical records may introduce selection bias and limit the generalizability of the findings. Additionally, the study did not consider the cost implications of advanced techniques, which may be a significant factor in their widespread adoption [18]. Future prospective studies with larger sample sizes and cost-benefit analyses are warranted to validate these findings and further explore the economic impact of advanced surgical techniques.

The results of this study have important clinical implications. The demonstrated benefits of advanced surgical techniques in terms of functional outcomes, complication rates, and recovery times should encourage their broader adoption in clinical practice. However, it is crucial to consider each patient's circumstances and the availability of resources when choosing the most appropriate surgical method [19].

Future research should focus on the long-term outcomes of advanced techniques, particularly the durability of corrections and the quality of life over extended follow-up periods. Additionally, exploring the potential of emerging technologies such as robotic-assisted surgery and the further integration of biologics may provide new avenues for enhancing the effectiveness of limb deformity corrections [20].

Summary

In summary, the advancements in surgical techniques for limb deformity corrections have markedly improved patient outcomes. This study highlights the superior functional and radiographic results, lower complication rates, and faster recovery times associated with advanced methods compared to traditional techniques. These findings underscore the importance of continued innovation and the adoption of advanced surgical approaches to improve the quality of care for patients with limb deformities. Embracing these advancements will not only enhance patient outcomes but also pave the way for future developments in orthopedic surgery.

CONCLUSIONS

In conclusion, the advancements in surgical techniques for limb deformity corrections represent a significant leap forward in orthopedic surgery. Embracing these innovations will lead to better patient outcomes, reduced complications, and faster recoveries, ultimately enhancing the overall quality of life for individuals with limb deformities.

The future of limb deformity correction lies in the continuous evolution and adoption of these advanced surgical approaches, paving the way for further improvements in patient care.

CONTRIBUTION OF AUTHORS

Research concept- P. Surya Prakash Naidu

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Supervision- Mandem Venkata Sudhakar

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Data analysis and Interpretation- Chalumuri Navya, Mamidi Sai Pratap Reddy

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Critical review- Mandem Venkata Sudhakar

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Final approval- Mandem Venkata Sudhakar

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DOI: 10.21276/SSR-IIJLS.2024.10.4.23

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