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Original Research Article

REIMPLANTATION OF STERILISED TUMOR TISSUE WITH ADJACENT BONE OF BONE SARCOMA BY EXTRA CORPOREAL RADIATION THERAPY

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ABSTRACT

Background: Limb salvage following resection of malignant bone tumours commonly relies on endoprosthetic reconstruction, which is costly and, in growing children, prone to limb-length discrepancy. Biological reconstruction using size-matched allografts or vascularised autografts is often limited by tissue-bank availability or graft volume. Extracorporeal radiation therapy (ECRT), in which the resected tumour-bearing bone is sterilised with a single 50 Gy dose of radiation outside the body and reimplanted, offers an autologous, low-cost alternative that preserves a perfect anatomical match without the long-term complications associated with prosthetic implants. **Materials and Methods:** This prospective interventional and retrospective study was conducted at R.G. Kar Medical College and Hospital on 24 patients with biopsy-proven, non-metastatic bone sarcoma who attended the orthopaedic OPD between December 2022 and January 2025 and satisfied the inclusion criteria for ECRT. Following oncologically safe intercalary resection, the bone was cleared of soft tissue and marrow, irradiated with a single 50 Gy dose, stabilised with appropriate fixation (with bone cement or fibular grafting as needed), and reimplanted. Patients were followed up clinically and radiologically, and functional outcome was assessed using the Musculoskeletal Tumour Society (MSTS) scoring system. **Results:** Of the 24 patients, 83.3% (n=20) were aged 11–20 years and 16.7% (n=4) were over 20 years; 58.3% (n=14) were male and 41.7% (n=10) female. Ewing sarcoma was the most common histological subtype (41.6%), followed by chondrosarcoma (29.2%), osteogenic sarcoma (16.7%), and mesenchymal chondrosarcoma (12.5%). The most frequently affected site was the right distal femur (16.7%). Wide resection with ECRT and reimplantation was the most common procedure performed (58.3%). Two cases (8.3%) developed non-union requiring revision surgery, and two (8.3%) developed mild soft tissue infection that resolved with conservative management; no local recurrence or metastasis was recorded in these cases. The mean follow-up period was 17.58 ± 1.77 months, and the mean MSTS functional score was 25.05 ± 0.90, indicating favourable functional recovery. **Conclusion:** ECRT with reimplantation of sterilised tumour bone is a mechanically stable, oncologically safe, and economical limb-salvage technique for bone sarcoma, offering satisfactory functional recovery with an acceptable complication profile. It represents a particularly valuable option in low-resource settings where costly prosthetic implants or tissue banks are unavailable. Longer-term studies with larger cohorts are warranted to confirm durability and refine patient selection.

INTRODUCTION

Strong chemotherapy medications, more advanced imaging technologies, and better surgical methods have made limb-preserving procedures for malignant bone tumours commonplace. The most popular reconstruction technique following cancer ectomy is still endoprosthesis. As the kid grows, this type of resection frequently results in a discrepancy in limb length due to the growth physis being removed across the joint.[1] To get around this, a growing prosthesis must be used, which can be extended after surgery using either invasive or non-invasive methods to account for the native limb's growth.[2] The majority of patients undergoing limb salvage surgery in their nation cannot afford these costly implants.

Sometimes the tumour can be removed with wide margins, saving the joint and the physis, especially in young children where the open physis might be taken as a wide margin. If a suitable tissue bank is available, size-matched allografts or intercalary implants can be used to bridge the bone deficiencies left by these resections. One benefit of the biological rebuilding approach is that, once integrated with the host bone, it is a lifelong process and is not linked to the problems associated with prosthesis use.[3] If a tissue bank is unavailable, an alternative method of biological reconstruction would be to use a vacularized or non-vascularized autograft, such as a fibula. However, it might occasionally be impossible to gather enough autografts to fill in significant bone deformities.[4] In some cases, sterilising and reimplanting the removed tumour bone is a feasible solution.

However, reimplanting the removed cancer bone following sterilisation is one restoration technique when an oncologically safe intercalary resection for malignant bone tumours is possible. Extra Corporeal Radiotherapy (ECRT) is the term for radiation administered outside the body to sterilise the tumour bone. Following resection, the bone is cleared of all soft tissue and bone marrow before being transported in a plastic container to the radiotherapy department, where it is exposed to 50 Gy of radiation, which destroys all cells, including tumour cells.

After being stabilised by the proper fixation devices and augmented with either bone cement or fibular grafts, the bone is returned to the operating room and reimplanted. Reimplanting the same bone has the benefit of providing a perfect match to the tumor-free removed bone. Following surgery, the joint is immediately mobilised, and weight bearing is initiated in accordance with the kind of fixation. Compared to the metaphyseal end, the diaphyseal end takes longer to join. Reimplanting the tumour following ECRT may not be mechanically sound if it has caused significant bone degradation or if it has a pathological fracture. Following tumour resection, ECRT is a mechanically stable and oncologically safe technique for biologically rebuilding bone defects.

Tumour bone can be sterilised using a variety of techniques, including autoclaving, pasteurisation, liquid nitrogen, and radiation.[5] By sterilising the bone for 20 minutes at 1210 C, autoclaving eliminates all cancer cells. However, it has the drawback of destroying Bone Morphogenic Protein (BMP),[6] and decreasing bone strength. Pasteurisation is the process of sterilising the specimen in a water bath at 650 C for 30 minutes. Although it offers the benefit of maintaining bone strength and BMP, maintaining sterility during the process is a real challenge.

Radiation therapy is the most widely used sterilising approach. The tumour bone is sterilised using 50 Gy of high-dose single-shot radiation. Extra Corporeal Radiotherapy (ECRT) is the process of administering radiation outside of the human body. The radiation dose must be administered outside of the human body since it is so intense that it kills all cells, including cancer cells. This approach has the least impact on the bone's mechanical strength, and there are sufficient articles in the literature to demonstrate that it is an oncologically safe method for sterilising cancer bone. Any higher radiation dose reduces mechanical strength and revascularisation and delays graft union and integration. 50 Gy of radiation is adequate to achieve tumour kill.[7] The pre-operative imaging is used to guide the resection. To guarantee sufficient tumour clearance, marrow curettings from both the proximal and distal cut ends are sent for frozen analysis.

specimen with soft tissue covering the tumour after intercalary resection. All of the soft tissue, periosteum, and medullary contents of the bone have now been removed. Suture tags are used to orient the excised soft tissue so that a histological analysis can determine the degree of tumour removal.

When compared to alternative limb salvage procedures, ECRT, a biological reconstruction technique, has a number of advantages, particularly for young adults and children. Since the "implant" is the patient's own bone, it is "patient-specific" and has a low risk of immunological reaction, enabling successful tendon reattachment to result in good healing and long-lasting reconstruction (Poffyn et al., 2011).[8] Additional benefits include not requiring expensive implants and/or numerous surgical procedures to accommodate patients' growth (as in metallic implants) or relying on a bone bank (as in allograft). ECRT is currently a well-established method that is being used in Asia and Europe (Sharma et al., 2013).[9]

In carefully chosen patient groups, this economical biological rebuilding technique has demonstrated positive clinical outcomes. ECRT is the only treatment accessible in many situations, such as low-resource settings where expensive implants are unaffordable and bone banks are unavailable. Therefore, a thorough clinical and biomechanical understanding of the surgery and its immediate and long-term consequences is crucial.[10]

MATERIALS AND METHODS

Study Design: Prospective interventional and Retrospective.

Study Setting: R.G Kar Medical College and Hospital.

Place of Study: Patients who attended the orthopaedic OPD in their hospital between December 2022 to January 2025. The patients were evaluated by Clinical examination, Radiological investigations and biopsy reports. The patients who were having biopsy proven bone sarcoma and who satisfy the inclusion criteria were selected for ECRT.

Inclusion Criteria

- Bone Sarcoma patients where limb salvage surgery is feasible.
- Neurovascular bundle not involved.
- Soft tissue coverage of implant and bone after resection is feasible.
- Non-Metastatic.

Exclusion Criteria

- Patients with pathological fractures.
- Patients with concomitant infective bone diseases.
- Non-Metastatic.

Period of study: 2yrs (December 2022 to January 2025) study population: Patients who attended the OPD with biopsy proven bone sarcoma.

Core needle biopsy in a representative patient (diagnostic step in our protocol)

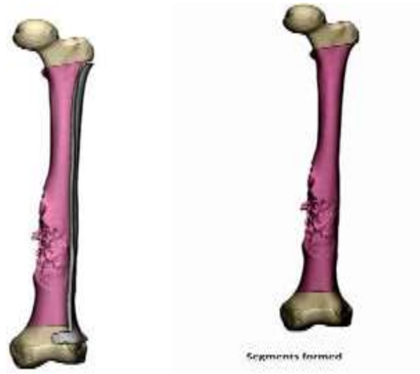

Figure: 3D printing of a representative case for pre-operative planning of osteotomy and reconstruction

RESULTS

Table 1: Distribution of Age in group

Age in group	Frequency	Percent
11-20	20	83.3%
>20	4	16.7%
Total	24	100.0%

The study included a total of 24 participants. The majority (83.3%) were in the 11–20 years age group (n=20), while the remaining 16.7% (n=4) were above 20 years of age. This distribution highlights that the predominant age range in the study was 11–20 years.

The value of z is 4.6188. The value of p is < .00001. The result is significant at $p < .05$.

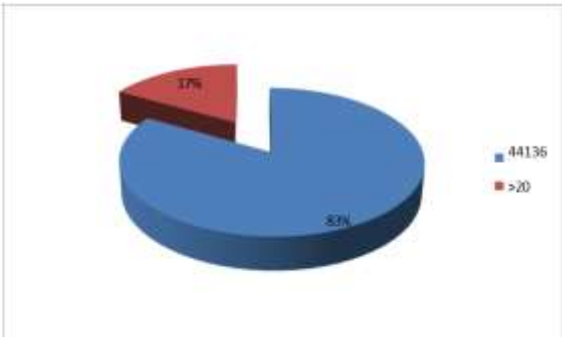

Table 2: Distribution of Sex

Sex	Frequency	Percent
Female	10	41.7%
Male	14	58.3%
Total	24	100.0%

Among the 24 participants, 14 (58.3%) were male, while 10 (41.7%) were female. This indicates a slightly higher representation of males in the study population.

The value of z is 1.1547. The value of p is .25014. The result is not significant at $p < .05$.

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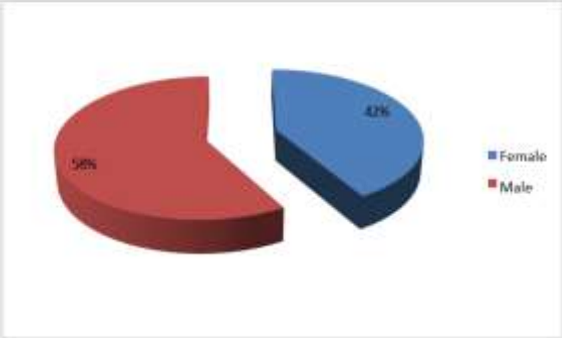

Table 3: Distribution of Histopathology

Histopathology	Frequency	Percent
Chondrosarcoma	7	29.20%
Ewing Sarcoma	10	41.60%
Mesenchymal Chondrosarcoma	3	12.50%
Osteogenic Sarcoma	3	16.70%
Total	24	100.00%

In our study, we analyzed the histopathological distribution of bone sarcomas. Among the cases evaluated, Ewing sarcoma was the most prevalent, accounting for 41.6% (n=10) of the total cases. Chondrosarcoma was the second most common histological subtype, observed in 29.2% (n=7) of cases. Osteogenic sarcoma constituted 16.7% (n=3), while mesenchymal chondrosarcoma was the least frequent, representing 12.5% (n=3) of cases.
The value of z is 2.2736. The value of p is .0232. The result is significant at $p < .05$.

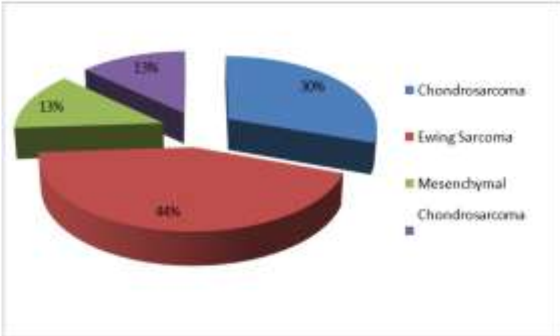

Table 4: Distribution of Anatomical Location

Anatomical Location	Frequency	Percent
Distal Femur Diaphysis	1	4.2%
Left Distal Femur	1	4.2%
Left distal Humerus	1	4.2%
Left Distal Tibia	1	4.2%
Left Femur diaphysis	2	8.3%
Left Hemipelvis	1	4.2%
Left Hemipelvis, sacrum	1	4.2%
Left Humerus	2	8.3%
Left proximal Femur	1	4.2%
Left proximal tibia	1	4.2%
Proximal femur	1	4.2%
Proximal Humerus	2	8.3%
Right Distal Femur	4	16.7%
Right distal humerus	1	4.2%
Right Distal Tibia	2	8.3%
Right proximal Femur	2	8.3%
Total	24	100.0%

The anatomical distribution of lesions among the 24 study participants varied across different skeletal regions. The most commonly affected site was the right distal femur, observed in 16.7% (n=4) of cases. Other frequently involved locations included the right distal tibia (8.3%, n=2), right proximal femur (8.3%, n=2), proximal humerus (8.3%, n=2), left humerus (8.3%, n=2), and left femur diaphysis (8.3%, n=2). Less frequently affected sites, each accounting for 4.2% (n=1) of cases, included the distal femur diaphysis, left distal femur, left distal humerus, left distal tibia, lefthemipelvis, left hemipelvis with sacrum involvement, left proximal femur, left proximal tibia, proximal femur, and right distal humerus.

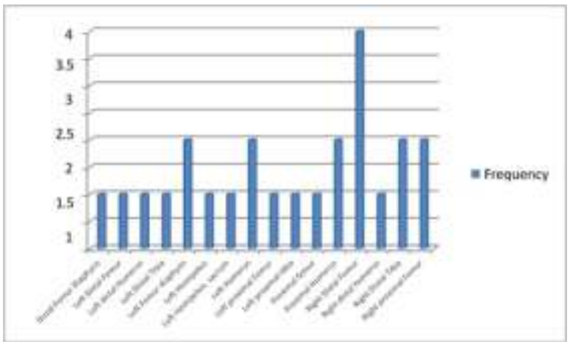

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Table 5: Distribution of Procedure

Procedure	Frequency	Percent
Complication(non-union) Distal site, needed revision	1	4.2%
Complication(non-union)needed revision surgery	1	4.2%
ECRT + Reimplantation	2	8.3%
ECRT + Vascularised Fibula + Reimplantation	3	12.5%
Left Side Hemipelvectomy + ECRT + Reimplantation	1	4.2%
Vascularized fibula graft + ECRT + Reimplantation	1	4.2%
Wide excision+ Hemipelvectomy + ECRT + Reimplantation	1	4.2%
Wide resection + ECRT + Reimplantation	14	58.3%
Total	24	100.0%

DISCUSSION

Patients who visited the orthopaedic outpatient department (OPD) between December 2022 and January 2025 were the subject of this prospective interventional and retrospective investigation, which was carried out at R.G. Kar Medical College and Hospital. Patients who met the inclusion criteria and had biopsy-proven bone sarcoma were chosen for extracorporeal radiation therapy (ECRT). Patients were assessed using radiological investigations, clinical examinations, and biopsy reports. The study cohort consisted of OPD patients with biopsy-proven bone sarcoma, and it took place over a two-year period, from December 2022 to January 2025.

Two significant complication instances were observed in our study. One was a 14-year-old child with distal femur diaphysial ewing sarcoma, proximal osteotomy site nonunion, and regular follow-up for 11 months without any distal metastases or local recurrence. After undergoing revision surgery with plating, he was referred for adjuvant chemotherapy and has been undergoing routine follow-up for the past six months.

In another instance, a 50-year-old male patient with proximal third shaft femur osteogenic sarcoma was treated initially with wide resection and ECRT. Ten months after surgery, the distal osteotomy site became nonunion, and there was neither a local recurrence nor any metastasis to other parts of the body. After undergoing revision surgery and six months of radiotherapy and orthopaedic follow-ups, he is now clearly united at both sites, and both patients are doing well both oncologically and functionally.

Two of the instances developed mild soft tissue infections, which were treated with complete aseptic dressings every other day. Both cases subsequently recovered without any issues. Ten men and four females with a median age of 14 were observed in a related study by Sharma DN et al. (2013). Histopathologically, five patients had Ewing's sarcoma family of tumours (ESFT) and nine had osteosarcoma (OS). The primary site was distributed as follows: eight patients in the femur, five in the tibia, and one in the humerus.

The bulk of participants in this study (83.3%) were between the ages of 11 and 20, suggesting that this age group made up the majority demographic. The remaining 16.7% were older than 20, indicating a far lower proportion of senior people. This distribution could be a reflection of the recruitment approach used or the inherent prevalence of the illness under study. The younger age group's prevalence may also have an impact on how the disease manifests, progresses, and responds to treatment, underscoring the need for focused therapies in this population. A more thorough knowledge of age-related differences may be possible with additional research including a wider age range.

Males made up a slightly larger percentage (58.3%, n=14) of the 24 participants than females (41.7%, n=10). This distribution indicates a little male predominance in the research population, which could be impacted by variables like sample selection criteria, healthcare-seeking behaviour, or disease prevalence. The distribution of genders may also affect how the disorder under inquiry manifests, develops, and is managed. Determining whether this trend is indicative of a larger population pattern or an incidental result unique to this study may be aided by additional research with a bigger and more balanced sample.

Ewing sarcoma is the most common histological subtype in our study (41.6%), followed by chondrosarcoma (29.2%), osteogenic sarcoma (16.7%), and mesenchymal chondrosarcoma (12.5%). A non-random distribution of these cancers is suggested by the statistically significant p-value (0.0232), suggesting possible underlying reasons driving their incidence. This discovery emphasises the significance of early detection and customised treatment plans for various sarcoma subtypes. To confirm these findings and investigate related prognostic implications, more research with bigger sample numbers is required.

The average follow-up period in this trial was 17.58 ± 1.77 months, which gave sufficient time to evaluate the intervention's long-term effects. This follow-up period is in line with earlier research assessing comparable clinical indicators, guaranteeing adequate monitoring for the course of the disease, the effectiveness of treatment, and any consequences. The comparatively small standard deviation indicates that participant follow-up times are consistent, which lowers outcome assessment variability.

A mean score of 25.05 ± 0.90 was found when the study participants' functional outcomes were analysed using the Musculoskeletal Tumour Society (MSTS) scoring system. This result points to a generally positive functional recovery after the

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intervention. The dependability of this outcome measure in evaluating post-treatment musculoskeletal function is further supported by the fact that prior research has revealed MSTS scores in a comparable range. The patients' satisfactory limb function, pain control, and emotional acceptance are indicated by the comparatively high mean score.

CONCLUSION

A possible limb-salvage method for reimplanting sterilised tumor-bearing bone in patients with bone sarcoma is extracorporeal radiation treatment (ECRT). By successfully eliminating tumour cells while maintaining the bone's biological and structural integrity, this technique promotes reintegration and functional recovery. Our research shows that autografts treated with ECRT offer a feasible reconstructive alternative with positive functional and oncological results. To evaluate issues such graft resorption, fracture, and local recurrence, long-term monitoring is necessary. The effectiveness and suitability of this strategy in orthopaedic cancer can be improved by more investigation and improvement in surgical methods, adjuvant treatments, and post-operative rehabilitation.

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