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Comparative Test of Reconstruction with the Modified Arthrodesis Metallic and Cement (MAMC) Technique and the Juvara Technique in Resisting Axial Compression After Distal Femur Resection

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A B S T R A C T

Background: Limb salvage surgery (LSS) is a crucial treatment for malignancies, which mostly affects the distal femur and proximal tibia. LSS encompasses biological and non-biological reconstructions, including megaprosthesis. However, limited access to megaprosthesis in developing countries has led to alternative methods like arthrodesis such as modified arthrodesis with metal and cement (MAMC). LSS may lead to complications, requiring careful technique and implant selection but none of them conduct research about mechanical test. This research was comparing the effectiveness of techniques like MAMC with Juvara, in mechanical axial loading perspective**. Methods:** In this true experimental study, conducted at the Metallurgy Laboratory of the Faculty of Engineering, Universitas Sriwijaya, femur and tibia bones from cattle were used. Five samples of each variable were used based on the purposive sampling method. The research focused on variables like deformity angle and yield point which assessed using X ray. Bone constructs underwent various fixation techniques, including MAMC and Juvara. Testing involved axial pressure on the femur head using a mechanical press machine. Statistical analysis compared implant angulation after compression between Juvara and MAMC techniques under 30 kg and 60 kg loads, ultimately measuring the yield point. **Results:** All five samples from each group, subjected to both 30kg and 60kg pressure, exhibited no discernible changes. The average yield point for the MAMC group was notably 160KgF higher than Juvara, with respective means of 296 and 126kgF ($p>0.05$). Further analysis employing an Independent T-test confirmed a significant disparity between the MAMC and Juvara techniques concerning the yield point with a p-value of <0.001**. Conclusion:** Both the MAMC and Juvara techniques in this study effectively supported 30 and 60-kilogram loads, demonstrating their suitability for full weight-bearing compression, with MAMC exhibiting significantly greater compression resistance compared to Juvara ($p = 0.001$).

1. Introduction

Bone cancer, especially osteosarcoma, is a disease that often attacks children and adolescents. This cancer attacks bone cells and can cause serious damage to the bones and surrounding tissue. Osteosarcoma most often occurs in long bones such as the femur (thigh bone) and tibia (shin bone). In advanced stages, bone cancer can spread to other parts of the body. To prevent this spread, doctors often perform bone resection surgery. This resection aims to remove all parts of the bone affected by cancer. In cases of cancer in the distal femur (lower end of the thigh bone), distal femur resection is the main option.[1-4]

Distal femur resection certainly has consequences, namely loss of function and mobility of the leg. Therefore, bone reconstruction is needed to restore function and mobility. Bone reconstruction aims to replace the resected bone, maintain leg stability and strength, and allow the patient to return to normal activities. The modified arthrodesis metallic and cement (MAMC) technique uses metal implants and cement to replace the resected bone. These metal implants can be rods, plates, or screws. Cement is used to attach metal implants to healthy bones. The advantage of the MAMC technique is that it provides strong stability and allows patients to return to normal activities. Meanwhile, the disadvantages of the MAMC technique are the risk of infection and implant-related complications as well as higher costs.[5-7]

The Juvara technique uses an autograft of the patient's fibula bone to reconstruct the resected bone. An autograft is a tissue graft taken from the patient's own body. In the Juvara Technique, the patient's fibula bone is removed and shaped to replace the resected distal femur bone. The advantages of the Juvara Technique are that it reduces the risk of infection and implant-related complications and lowers costs. Meanwhile, the disadvantage of the Juvara Technique is that long-term stability has not been proven and requires a longer recovery time.[8,9] Currently, there is still no research to definitively show which reconstruction technique is superior. Research is still ongoing to compare the two techniques in terms of stability, risk of infection, and patient quality of life. This study aims to compare the ability of the two techniques to resist axial compression.

2. Methods

This research uses true experimental research. This research has an "experimental studies post test only" design, that is, with a design where there are 2 groups given the same treatment, and then the results are observed and compared**.** This study was conducted at the Engineering Materials/Metallurgy Laboratory, Faculty of Engineering, Department of Mechanical Engineering, Universitas Sriwijaya Indralaya, Indonesia. Research Time from January 2023 – August 2023. The object of this research is the femur and tibia bones of Madurese cattle (Bos incidus). This research uses the method of purposive sampling; a total of 10 research objects were included in this study, and the research objects met the inclusion criteria. The inclusion criteria in this study were a pair (right and left) of adult bovine bones, femur and tibia, and bovine bones with a length of more than 80 cm measured from the proximal femur joint to the distal tibia joint.

Bones that have been cleaned of muscles, ligaments, and capsules are stored in a freezer at -20 degrees Celsius and taken to the laboratory using an ice box along with hailstones. The femur bone was resected 10 cm from the joint line proximally with a Krisbow hand grinder. At MAMC, the intramedullary installation of 2 nails overlapping the femur and tibia has been done by an open cortex with a drill. Then the bones that have been nailing are fixed with plating DCP 4.5mm with screw as many as 6 cortices on each bone, and the remaining hole in the middle is provided with a cortical screw, then fixed with Orthocem 3 cement. In the Juvara technique, longitudinal resection is carried out on the proximal tibia as much as 12 cm in the coronal plane to the distal direction, 3 cm in the coronal plane of the distal femur, 3 cm in the proximal direction using Krisbow hand grinder. The bone from the anterior tibia is taken and then turned 180 degrees vertically. The bone is then fixed with overlapping 2 K-nails and performed screwing Anteroposterior 4 pieces.

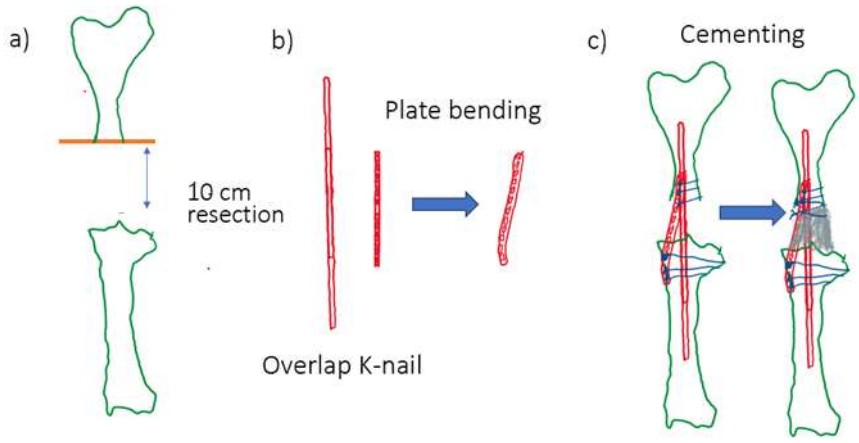

Figure 1. Illustration of the MAMC technique on cow bones. a) bone preparation resected 10 cm distal to the femur, b) preparation plate and nail, c) the bones are fixed and given augmentation with bone cement.

Cow bones that had undergone arthrodesis reconstruction were placed on the Universitas Sriwijaya engineering lab press machine with the TORSEE brand in 1997 with a test capacity of 3 TF. The subject is placed standing distally with pressure on the head femur, and then the press machine is turned on, pressing the subject axially. The amount of force/load that appears on the computer machine is recorded as data in kilogramforce (kgf) units which are printed on the machine. After the arthrodesis resection was carried out, the sample was X-rayed using an X-ray machine at the Dr. Mohammad Hoesin General Hospital in Palembang, Apelem brand. The X-ray beam shoots anteroposteriorly (AP) and laterally toward the subject. The sample taken is a sample with alignment K-nail 0±10 degrees valgus, flexion ±0-10 degrees. The degree of deformity is measured using goniometry on AP photos and lateral photos based on the anatomical axis of the femur and tibia. The first load was given as the first load of 30kg, and then the subject underwent an X-ray. A second test was carried out. Namely, an axial load was given to a sample weighing 60 kg, and then the subject underwent an X-ray again. In the last test to test the yield point in construction, compression is carried out until the deformity is visually visible for the first time, and then the pressure is reduced. The load is recorded, and pressure is applied again with an additional 5 kilograms of the previous load until irreversible deformity appears.

Statistical testing was carried out using the Stata version 15 program for Macintosh. Data analysis was carried out in two stages, namely, normality testing and mean difference testing. The normality test with Shapiro Wilk aims to determine whether the data is normally distributed or not, while to determine the use of the average test, you can use a parametric or non-parametric test. If the distribution is normal, the independent t-test is used, whereas if it is not normally distributed, then the Mann-Whitney test is used to determine whether there is a significant difference between the inclination of the implant angle after compression using the Juvara and MAMC techniques with a load of 30kg and 60kg. Finally, a test is carried out to measure yield point; that is, the subject is compressed until visually visible angulation deformity is irreversible.

3. Results

Analysis was carried out using an independent T-test, which shows that there is a difference in value between the MAMC and Juvara techniques in the group yield point (KgF) with p value=<0.001 (Table 1).

Table 1. Comparison of yield points for MAMC and Juvara techniques.

Yield point	Average (Kg/F) ± SD	p-value
MAMC	286 ± 28,3	0,001
Juvara	126± 11,4	

4. Discussion

In patients who do limb salvage, it is hoped that the patient will achieve limb function by being able to perform full weight bearing gradually. Using nails is superior compared to other options, such as plating or an external fixator. Knee arthrodesis surgery allows the patient to be able to mobilize without pain while recovering. Ambulation can be assisted with a cane or shoe lift if a discrepancy occurs. In the Juvara technique, the function of weight bearing is done after the fusion has occurred, so it requires time and a process that will slow down better limb function. Apart from that, the Juvara technique is known to have high complications such as intraoperative bleeding, non-union, implant failure, and infection, which can lead to amputation. Then, there is a delay in adjuvant chemotherapy in tumor patients because they hope for union first. Tumor patients, both sarcomas and giant cell tumors, which have been bone resection arthrodesis with Juvara, showed that more than 50% of patients union in less than 3 months. When compared with the MAMC technique, patients can perform weight-bearing faster with minimal risk of complications.[10-12]

The MAMC technique is known to have a musculoskeletal Society Tumor Score (MSTS) is good, even 40% have categorized it as excellent, and 50% categorize good with this fairly high MSTS score; research proves that the technique arthrodesis MAMC and Juvara can withstand axial loads with the average weight of the Indonesian population, namely 60 kilograms. This indicates that with both techniques, patients can easily bear partial and full weight bearing with the average Indonesian body weight. This research uses cow bones because, based on previous research, the mechanical properties of cow bones have higher elasticity young's modulus compared with human bones (117.49 ± 61.53; and 77.36 ± 54.96), while ultimate strength between the two is almost the same (6.52 ± 4.24; and 6.76 ± 5.21). Cow bone density is considered suitable as a substitute for human bone in orthopedic research, considering that human bone is difficult to research due to ethical and bone procurement issues. Density and young modulus human and bovine bones, respectively, are 2100 vs. 2000 (kg m^{-3}) and 17 vs. 22 (Gpa). The comparison between the two techniques does not change when given a compression load of 30 and 60 kg, indicating that both techniques are still in elasticity. Young's modulus, while there is a difference in strength yield point (p=0,001). In this study, the average strength Yield point MAMC is 286 kgF± 28.3, while Juvara is 126 KgF; ± 11,4.[13-15]

In knee arthrodesis with interlocking nailing on trial, once you obtain load to failure, it reaches 500 - 700 lbs (226-317 kg). This is comparable to the reconstruction technique after distal femur resection using MAMC, which has a yield point average of 286 kg. If it is related to the pressure received by the knee, the highest compressive force is obtained during the initial phase of standing. It was found that the highest peak force received by the entire knee joint was 3.28. times body weight (1.98 x BW on the medial side of the knee compartment and 1.30 x BW on the lateral side of the knee compartment). The greater force is received by the medial side. If linked to this theory, the MAMC technique is still within safe limits with a calculation of 87.2 kgF (286 kgF/3.28) as the limit, while Juvara's is 38.4 kgF (126 kgF/3.28).[16,17]

5. Conclusion

The MAMC and Juvara techniques from this study can withstand loads of 30 and 60 kilograms, as evidenced by X-rays that show that they do not change post-compression. It was concluded that both techniques can withstand compression forces full

weight bearing with the average weight of Indonesian society. There was a significant difference (p = 0.001) in compression resistance arthrodesis with the MAMC technique compared to the Juvara technique, so the MAMC technique is more able to withstand compression resistance.

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