Hypothesis

Single-Stage BMAC in a Collagen Scaffold Achieves Hyaline-Like Regeneration Superior to Micro fracture and Equivalent to ACI in Medium/Large Knee Defects

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Abstract

Background: Focal full-thickness chondral defects of the femoral condyles cause persistent knee pain, swelling and reduced function in adults. Articular cartilage has limited healing potential, so symptomatic lesions frequently become chronic and may contribute to early osteoarthritis. Surgeons manage these defects with techniques such as microfracture, osteochondral graft transfer, autologous chondrocyte implantation and single-stage biologic augmentation using bone marrow aspirate concentrate. Selecting the optimal approach depends on lesion size, location, patient age, activity goals and coexisting knee pathology.

Hypothesis: Surgical intervention for symptomatic full-thickness femoral condylar defects will produce meaningful improvements in pain and function at one year across commonly used techniques when the procedure is matched to lesion and patient characteristics. Younger age, lower body mass index and shorter symptom duration are expected to be associated with larger gains in validated patient-reported outcomes. Regenerative procedures may demonstrate superior structural repair on imaging, but early clinical improvements are predicted to be similar across appropriate techniques.

Clinical importance: This study offers practical guidance: individualized surgical care can reduce symptoms and restore knee function within a year, usually with low complication rates when standard perioperative pathways and rehabilitation are followed. Focusing on modifiable factors such as weight management and timely referral can improve outcomes. Where resources or logistics limit options, single-stage techniques provide a pragmatic route, while cell-based restoration remains valuable for larger defects when long-term tissue quality is a priority.

Future research: Randomized, longer term trials with standardized rehabilitation, routine MRI assessment and, where feasible, tissue evaluation are needed to compare durability between marrow-stimulation and regenerative strategies. Economic analyses and return-to-activity metrics should be incorporated to guide value-based care. Including patient-reported quality of life measures and stratified subgroup analyses will improve applicability across diverse patient populations.

Keywords: Chondral defect, Femoral condyle, Cartilage repair, Microfracture, Autologous chondrocyte implantation, Bone marrow aspirate concentrate


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DOI: https://doi.org/10.13107/jmt.2024.v10.i01.224

Background

Articular cartilage is the smooth, slippery tissue that allows our knee joints to glide and bear weight. When a focal full thickness chondral or osteochondral defect develops on the femoral condyles, patients typically experience pain, swelling, and reduced ability to walk, run or return to sports. Because cartilage has very limited capacity to heal on its own, these defects can persist and sometimes lead to early joint degeneration if not treated appropriately [1, 2]. Painful cartilage lesions are common findings at knee arthroscopy, reinforcing the need to choose effective, patient centred treatment options [3,4].

Over the years, surgeons have developed three broad strategies to manage symptomatic focal cartilage defects: palliative procedures (for example, arthroscopic debridement), reparative methods (most commonly microfracture), and restorative or regenerative techniques (such as osteochondral grafts and cell based therapies) [5–7]. Each approach has pros and cons. Microfracture is simple and inexpensive and often helps small to medium defects—especially in younger patients—but the repair tissue tends to be fibrocartilage rather than true hyaline cartilage and may wear out sooner in larger or high demand lesions [8–10]. Osteochondral autograft transfer (mosaicplasty) replaces the damaged area with native hyaline cartilage from a non weight bearing site and works well for small defects, but it is limited by donor site issues and the practical size of the grafts [11, 12]. Fresh osteochondral allografts can treat larger defects without donor site morbidity but bring logistical and availability hurdles [13].

Cell based restoration, such as autologous chondrocyte implantation (ACI) and matrix assisted ACI, aims to restore a surface that more closely resembles native cartilage; these techniques have shown durable benefits in selected patients, particularly those who are younger and more active [14–16]. In recent years, one stage biologic approaches using bone marrow aspirate concentrate (BMAC) or platelet rich products on scaffolds have become popular because they try to combine regenerative potential with the convenience and lower cost of a single operation; early reports suggest promising clinical and MRI results, although long term data are still limited [17–19].

Picking the right treatment comes down to matching the patient and the lesion. Important considerations include the size and location of the defect, the patient's age and activity goals, body weight, limb alignment, and whether other knee problems (meniscal tears, ligament injuries) need addressing at the same time [20–22]. The scientific literature includes many case series and some comparative studies, but randomized trials remain few and the results are mixed, which means surgeons often make decisions based on a combination of evidence, experience and patient preference [23,24].

This synopsis draws on a prospective single centre cohort that compared three commonly used strategies—microfracture, two stage ACI and single stage BMAC—for symptomatic full thickness femoral condylar defects larger than 2 cm^2. Outcomes were tracked using validated patient reported tools (IKDC and KOOS) at baseline, 6 months and 12 months, and MRI (MOCART) where available. The aim was practical: to describe short term improvements patients can expect, and to identify which patient factors most strongly influence those results.

Hypothesis

The central idea guiding this study was straightforward: surgical treatment for symptomatic full thickness femoral condylar defects will lead to meaningful improvement in pain and function by one year, but the size of that improvement depends more on patient factors—age, body mass index (BMI), and how long the problem has been present—than on the specific technique used when each procedure is chosen appropriately.

More specifically:

- We expected that microfracture, ACI and BMAC would each produce measurable and clinically important gains in IKDC and KOOS scores at 6 and 12 months compared with where patients started before surgery. While ACI and BMAC target regeneration and might show better tissue repair on imaging, short term functional gains in real world practice may be similar across techniques when surgeons select patients to match the strengths of each approach [8, 14, 17].
- Younger patients, those with lower BMI and those who have surgery soon after symptoms begin were expected to do better regardless of surgical choice. These factors make biological sense: younger tissue heals more readily, lower body weight reduces mechanical stress, and treating the problem earlier may prevent chronic changes that blunt repair [20–22].
- Imaging—MRI MOCART scores and, where available, second look inspection—was expected to show superior structural fill with regenerative approaches (ACI, BMAC) compared with microfracture. However, we believed that better MRI appearance would not always translate into vastly superior patient reported function within the first postoperative year, because tissue maturation and adaptation take time [16, 18].
- From a safety and practicality perspective, single stage procedures (microfracture, BMAC) should be more convenient and less costly, while ACI would be more resource intensive but potentially more suitable for larger defects.

These hypotheses shaped the analyses: we compared score changes over time between groups and used multivariable models to test which patient factors independently predicted better outcomes.

Discussion

In this cohort, patients treated for full thickness femoral condylar defects showed meaningful improvements in function and symptoms at 6 and 12 months after surgery. Across the three techniques—microfracture, ACI and BMAC—patients

generally improved and differences between groups at one year were small. This suggests that when surgeons pick the right patient for each procedure, different surgical strategies can all lead to worthwhile short term benefit [8, 16, 17].

Two patient characteristics stood out as predictors of better recovery: younger age and lower BMI. Patients who had surgery sooner after symptom onset also tended to do better. These findings reflect common clinical sense and prior reports: biological healing potential, lower mechanical loading, and avoiding chronicity help drive recovery [20–22].

MRI evaluation tended to favour regenerative approaches (ACI, BMAC) in terms of defect fill and surface congruity. Still, better imaging did not always equate to better patient reported outcomes at one year. This mismatch between image and symptoms is well recognized—patients feel better for many reasons beyond the tissue seen on MRI, and repair tissue continues to remodel after the first year [16, 18]. Complications were infrequent and mostly minor in this series.

The study has limitations worth noting. It was not randomized and reflects single centre experience, so selection and surgeon biases influence which patients received which treatment. The sample size was modest and follow up limited to one year, which is too short to comment on long term durability or the potential to prevent osteoarthritis. Also, we lacked histologic confirmation of repair tissue in most cases, which limits conclusions about the exact quality of the new cartilage.

Despite these limitations, the practical message is clear: surgical repair for symptomatic focal full thickness chondral defects can produce meaningful short term improvements, and clinicians should consider patient factors (age, BMI, timing) when choosing among effective options. In settings where resources or logistics constrain choices, single stage options like microfracture or BMAC can be reasonable, while ACI remains an option for larger defects where restoring hyaline like tissue is a priority.

Clinical Importance

Painful chondral defects of the femoral condyle limit activity and reduce quality of life. This study shows that, with appropriate case selection, microfracture, ACI and BMAC each can substantially reduce symptoms and improve knee function within a year of surgery, with low rates of complications. Younger patients, those with lower BMI, and those treated earlier after symptom onset are more likely to experience better outcomes. Discussing these factors openly with patients helps set realistic expectations and tailor treatment to individual goals.

Future Directions

Longer follow up studies, ideally randomized, are needed to compare durability between marrow stimulation and regenerative strategies. Research should combine patient outcomes with standard MRI scoring and, where possible, tissue sampling to link repair quality with long term function. Economic analyses and return to activity measures will also help clinicians choose cost effective treatments for different patient groups.

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Conflict of Interest: Nil

Source of Support: None

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University Affiliation: MUHS, Nashik, Maharashtra, India.
Year of Acceptance of Thesis: 2022

How to Cite this Article: Patwardhan S, Sancheti P, Patil K, Gugale S, Sanghavi S, Sisodia Y, Nisar OU, Sonawane D, Shyam A. Single-Stage BMAC in a Collagen Scaffold Achieves Hyaline-Like Regeneration Superior to Micro fracture and Equivalent to ACI in Medium/Large Knee Defects. Journal of Medical Thesis. January-June 2024; 10(1):54-57.