Journal of Cartilage & Joint Preservation® xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Cartilage & Joint Preservation®

journal homepage: www.elsevier.com/locate/jcjp

Technical Note with Video

Treatment of large chondral lesions with big bony defects: the Overlay autologous chondrocyte implantation technique

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A R T I C L E I N F O

Keywords:
Big bony defect
Bone graft and ACI
Extra-large osteochondal lesion
Large chondral lesions
Overlay ACI

A B S T R A C T

Introduction: The treatment of large chondral defects is more challenging when these chondral lesions are associated with big bony defects, which may be present in the form of either multiple subchondral (SC) cysts, or necrotic area of SC bone plate and SC spongiosa or as total fragmentation of the condylar surface. Looking to the young age of such patients, preservation of the joint is essential to prevent an early onset osteoarthritis. The marrow stimulation techniques and autologous chondrocyte implantation (ACI) need healthy SC bone to regenerate cartilage, while the osteochondral cylinder transfer techniques have donor size limitations.

Objectives: A new technique to treat large chondral lesions with big bony defects is described here in step-by-step manner and is called the overlay ACI technique.

Methods: The overlay ACI technique combines principles of autogenous bone grating for the treatment of large bony defects, which is followed by an overlay of ACI in a conventional manner to treat cartilage lesion.

Results: The overlay ACI technique provides an autogenous solution in form of a pain-free biological joint without any sequelae to the host tissue and formation of the hyaline (like) cartilage.

Conclusion: The presence of large chondral lesions with big bony defects is a surgical joint preservation challenge. The overlay ACI technique is a promising technique to treat extra-large osteochondral lesions with an autogenous solution.

Introduction

Large cartilage lesions are often associated with big bony defects in the form of either subchondral (SC) bone disruptions, discontinuity, collapse or big SC cysts depending on etiology and chronicity.[1] The common causes of such lesions are big osteochondritis dissecans, focal osteonecrosis, or a major osteochondral injury. Most of such lesions occur during teen to mid-age years, making joint preservation more essential.[2] Such lesions have a less favorable prognosis with a strong tendency to cause a painful joint and early onset osteoarthritis. The solution is either preservation or sacrifice.[3] While sacrifice means replacement surgery at a very young age, preservation means a big challenge with unpredictable results.[1,3,4] The techniques like marrow stimulation and autologous chondrocyte implantation (ACI) are not meant to be used in association with unhealthy SC bone. The osteochondral cylinder transfer techniques are promising for small to mid-size lesions with bony defects, but these techniques cannot be used for large lesions. Allografts transfers are also a popular option for combined

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https://doi.org/10.1016/j.jcjp.2024.100178
Received 30 January 2024; Revised 4 March 2024; Accepted 13 March 2024
Available online xxxx

Please cite this article as: D. Goyal, Treatment of large chondral lesions with big bony defects: the Overlay autologous chondrocyte implantation technique, Journal of Cartilage & Joint Preservation®, https://doi.org/10.1016/j.jcjp.2024.100178

cartilage and bony defects but have cost, regulatory and infrastructure issues, apart from vulnerability to unknown disease transfer. From the perspective of a global solution, as with ACI, allografts also have limited availability.[5]

Autogenous osseous bone grafting is a widely accepted and practiced method for filling and restoration of the big osseous defects. ACI is also a commonly used method to treat large and extra-large chondral defects. First described in 2011, "The Overlay ACI Technique" combines single-stage autogenous osseous restoration with ACI based repair procedures to treat extra-large osteochondral lesions.[6] The SC osseous restoration is done using autogenous iliac crest bone graft and chondral repair is done using gel based ACI. The overlay ACI technique is a challenging surgery but can potentially give a pain-free biological joint without any sequelae to the host tissue and formation of the hyaline (like) cartilage.[7] A step-by-step technical note for the overlay ACI procedure is described here along with advantages, risks, limitations and a video.

The overlay ACI technique

Step 1: The ideal case selection

A young patient (preferable age < 45-50 years) with an extra-large chondral lesion with a big underlying bony defect with biomechanically normal/corrected joint is an ideal case for the overlay ACI technique. The patient should also be ready for extensive rehabilitation compliance. The cases that cannot be treated by more conventional methods like osteochondral cylinder transfer techniques or an isolated ACI procedure should only be selected.

Step 2: The arthroscopic assessment of the lesion

The first stage arthroscopy procedure, in addition to allowing the surgeon to obtain a cartilage biopsy, also allows the surgeon an opportunity to assess the bony and chondral defect. Removal of a loose body (Fig. 1A) or removal of the fragmented osteochondral surface (Fig. 1B) are also performed at this first procedure, to allow better function for the patient until the second stage surgery. Removal of loose fragment will also give an opportunity to analyze the underlying bony defect, its exact size and its depth. A surgeon may choose to debride the bony defect until healthy bone at this stage and may get further idea of the exact size, location of the bony defect, or the surgeon may keep final preparation of the bony bed pending till the second stage (step 6). A simultaneous assessment of the possible method to reconstruct the bony defect must be made at this stage. The surgeon must also plan, how is he going to stabilize the bony graft into the large bony defect. For example, a chondral defect in the central location of medial femoral condyle can be treated by bone graft that is press-fitted into the defect, as medial and lateral wall of the condyle will provide stability. However, a total separation of posterior part of lateral femoral condyle along with its cortical walls, will warrant a tricortical graft and fixation with headless screws.

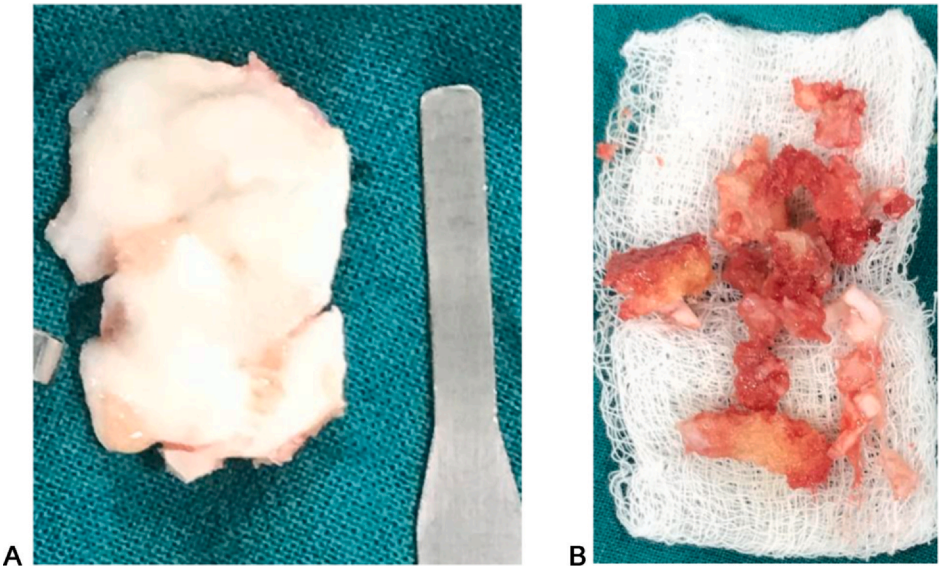

Fig. 1. A, A large osteochondral condylar piece is separated from posterior part of lateral femoral condyle. The piece includes chondral surface, subchondral bone plate and spongiosa including medial and lateral condylar walls also. **B**, Multiple fragmented osteochondral pieces separated from posterior part of lateral femoral condyle.

Step 3: The cartilage biopsy

The method to take cartilage biopsy varies from surgeon to surgeon. While some surgeons and some cartilage labs recommend taking a sliver of cartilage from the lateral trochlear margin, a few cartilage labs (eg, Regrow Biosciences Pvt Ltd, India) recommend using a hexagonal harvester to harvest the chondral biopsy. The surgeon should use the method of his acquaintance to take the cartilage biopsy. The most convenient way to take the biopsy from the preferred sites of either the medial or lateral trochlear margins is to keep the knee fully extended, which ensures preferred site to be above the linea terminalis. By remaining above linea terminalis,

Fig. 2. **A**, A hexagonal harvester is used to take the biopsy from the preferred site of either the medial trochlear margin or the lateral trochlear margin, while keeping the knee extended. The harvester is put perpendicular to the chondral surface and hammered till 5 mm mark. **B**, A chondral biopsy harvest till 5 mm ensures harvesting of full thickness of cartilage till subchondral bone plate. **C**, The chondral biopsy is transferred to the transport vial directly from the harvester and sent to the cartilage lab.

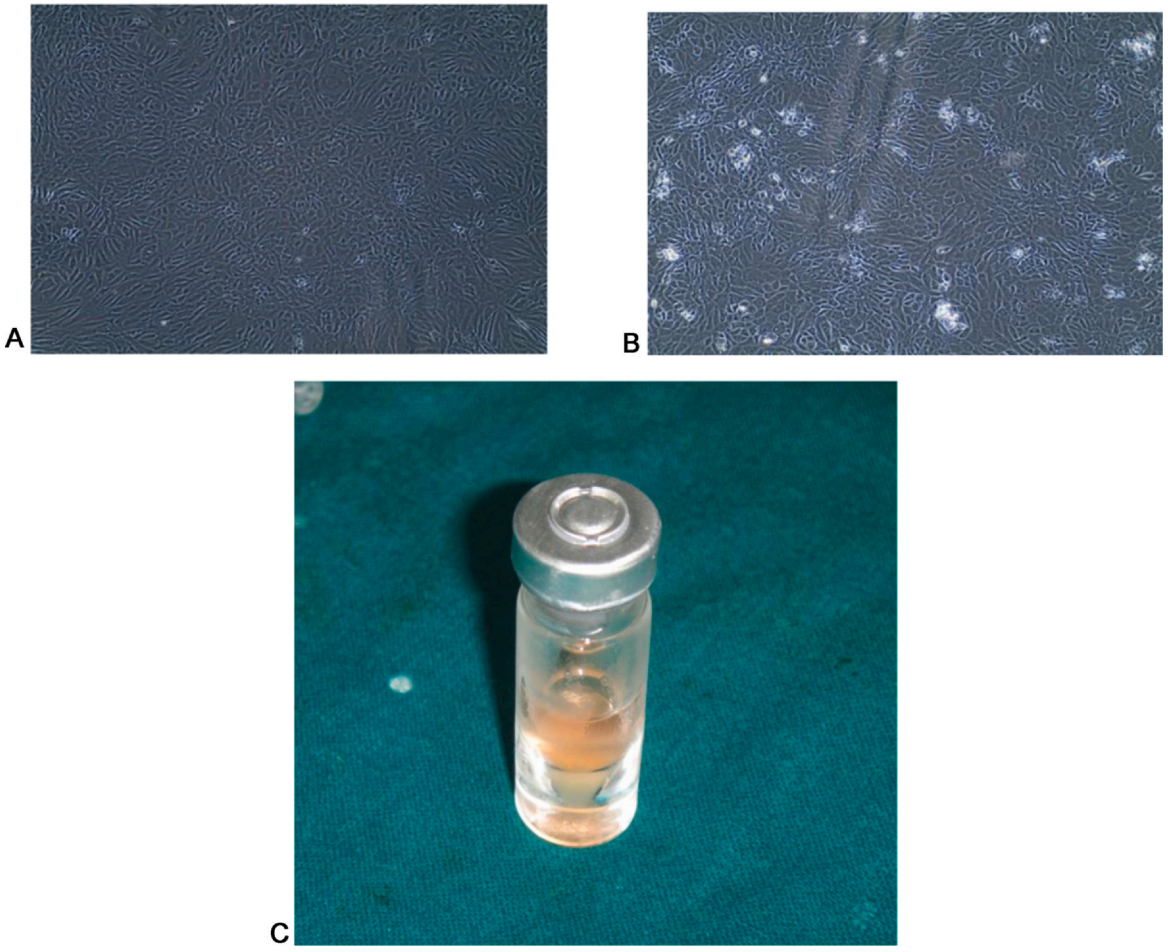

Fig. 3. **A**, The isolated cells from the chondral biopsy are subjected to frequent medium changes till targeted cellular confluency of around 80% is achieved. **B**, The cells are passaged multiple times till the required cell count and cell viability of 48.64 × 10^6% and 98.68% is reached respectively. **C**, The cultured cells are supplied in V-vials under strict temperature control.

the surgeon is assured of not violating the weight bearing articular surface of femoral condyles. The surgeon should put the trocar-cannula perpendicular to the chondral biopsy site (Fig. 2A), and then the trocar is removed. The cannula is hammered until 5 mm mark. This ensures a full thickness of the cartilage being harvested with a minimal base of the SC bone (Fig. 2B). The trocar is used again to push the chondral biopsy from the harvester, directly into the transport vial for transportation to the cartilage lab (Fig. 2C).

Step 4: The chondrocytes culture and cells delivery from the cartilage lab

The chondral tissue biopsy is transported under controlled temperature conditions to the cGMP (current good manufacturing practice) certified cartilage lab, where tissue is subjected to gross processing and enzymatic processing to isolate chondrocytes. A 132 mg of cartilage biopsy tissue usually yields 1.56 × 10^5 cells at the time of isolation.[8] The isolated cells are subjected to frequent medium changes till targeted cellular confluency of around 80% is achieved (Fig. 3A). The cells are further enzymatically harvested and seeded for the next step. The cells are passed through several passage till the cell count and cell viability reaches 48.64 × 10^6% and 98.68%, respectively (Fig. 3B). For a 1 cm^2 defect, approximately 12 million cells are required. A total of 12 million cells are supplied in a vial that is V shaped at the bottom. Generally, 4 such vials with 12 million cells each is supplied[8] (Fig. 3C). Depending on the final expected size of the chondral lesion, the surgeon should demand appropriate numbers of cells at the time of sending the cartilage biopsy itself. The final cultured chondrocytes are transported back to the hospital keeping a cold chain (maintaining and monitoring a continuous temperature at 2-8 °C) for the implantation. Sterility control is kept throughout the process and frequent culture for bacterial growth are done. Each cartilage lab has their own proprietary method to culture the cells and the surgeon should choose the cartilage lab of acquaintance for the same.

Step 5: Identifying an ideal surgical approach

The second stage surgery is either an open or a mini-open surgery, which is needed for the management of the large bony defects as well as for the simultaneous implantation of ACI. The selection of the ideal surgical approach depends on the location and accessibility of the lesion. A mini medial or lateral parapatellar approach for the medial or the lateral femoral condylar defects respectively, is usually sufficient. However, a large defect on the posterior part of the lateral femoral condyle may need a popliteal approach. For a large trochlear defect, a standard medial parapatellar arthrotomy is needed.

Step 6: The preparation of the bony defect

The basic principle to manage large bony defect is to debride all the debris and the necrotic bone from the bony defect/SC bone lesions; before a bony restoration is attempted. There are 3 types of bony defects that a surgeon would usually encounter, and the preparation of the defect differs accordingly. The first type of large defect can be in the form of multiple SC cysts with areas of necrosis but has intermittent healthy and intact SC bone plate (Fig. 4A). In such lesions, the cysts are excavated and curetted until the healthy margins, using appropriately sized curettes. The healthy intermittent SC bone plate areas are kept intact. The second type of

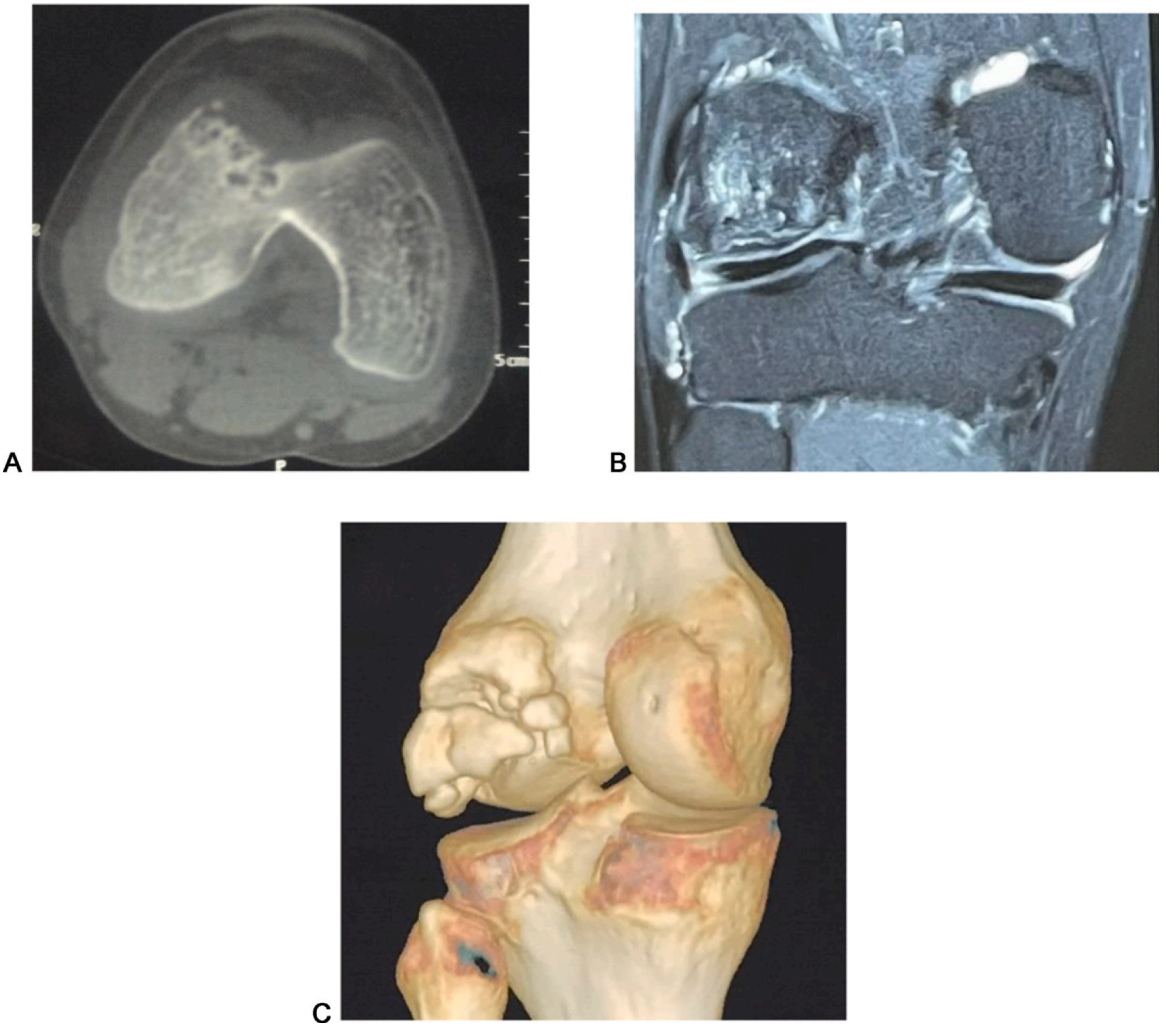

Fig. 4. The large chondral lesions are commonly associated with either of 3 types of big bony defects. **A**, A large trochlear defect in male aged 13 years is showing multiple cyst formation with intermittent healthy and intact subchondral bone plate. In such cases the cysts are filled with necrotic bone which must be curetted out till healthy margins in each cyst. **B**, A large area of osteonecrosis is seen in lateral femoral condyle in a male aged 23 years. The osteonecrotic area is involving the SC bone plate and SC spongiosa underneath. However, the medial and lateral cortical walls of the lateral femoral condyle is intact. In these types of cases, the necrotic SC bone plate and the spongiosa underneath must be removed while the healthy walls should be preserved. **C**, The third type of bony defect usually involves posterior part of lateral femoral condyle where the whole posterior condyle is necrotic and either it gets fragmented into multiple pieces or the whole posterior condyle gets separated. SC, subchondral.

bony defect presents as a large area of SC bone plate necrosis along with necrotic SC spongiosa (cancellous bone) underneath (Fig. 4B). However, the cortical condylar walls on either side are intact and healthy in such lesions. All the dead SC bone plate and SC spongiosa bone are removed with the help of appropriately sized osteotomes till healthy SC spongiosa bed is reached. It is important to discard all the dead bone from the side walls also till the healthy cortical walls are reached. The third type of bony defects comprise of a total separation of the large condylar piece along with the surrounding walls (Fig. 4C). In such cases, the bed of the separated unit is made raw and freshly bleeding, while all the necrotic bone piece(s) is/are discarded.

Step 7: The reconstruction of the large bony defect

The creation of a healthy bony base and the healthy bony margins as in previous step is a prerequisite for the success of this step. The iliac crest autograft is the ideal source of bony restoration during the overlay ACI procedure. After creating the healthy environment, it is crucial to decide the type of bone graft that the bony defect would need; a pure cancellous graft, a cortico-cancellous graft, or a tricortical graft. The type of bony restoration depends on the type of the bony defect. (1) A bony defect with multiple cysts with intact SC bone plate in-between the cysts (Fig. 5A) are largely treated with packing of the cancellous bone graft into the cysts after the cysts are prepared as per step 6. The cancellous iliac crest bone graft is impacted into the SC cysts till the level of the SC bone plate, thus reconstructing the SC spongiosa and the SC bone plate. (2) The large bony defect comprising loss of SC bone plate and underlying spongiosa with intact medial and lateral margins of the condyle (Fig. 5B) is treated as per the Table. A bony defect deeper than 8 mm is reconstructed using a tricortical iliac crest graft (with decorticated walls) (Fig. 5C), while a bony lesion with a defect depth of 4 to 8 mm is reconstructed using pure cancellous bone graft. Any lesion that has < 4 mm defect depth is treated with ACI alone. (3) A total loss of condylar piece including all margins, for example a total separation of the posterior part of the lateral femoral condyle is treated with a size matched tricortical iliac graft which is fixed with either a headless screw or a Herbert screw (Fig. 5D).

Step 8: The preparation of the ACI implant

Once an osseous reconstruction is achieved, the chondral defect can be treated as per standard ACI procedure. A surgeon might anticipate a significant oozing from the reconstructed osseous bed; but, this is usually not the case. The fibrin gel may act as an added sealant. A gel based autologous chondrocyte implantation (ACI) is used by the author,[8] however, any other modern generation of ACI can also be used. A proprietary preparation method is used to prepare the final implant using multiple vials and 2 different syringes.[8] The first syringe contains 1 mL fibrinogen while the second syringe contains 0.9 mL of cultured chondrocytes and 0.1 mL of thrombin. Two 1 mL syringes are connected with a “Y” mixing connector (Fig. 6). Each drop of the syringe contains a mix of chondrocytes and thrombin-fibrinogen mixture that forms the fibrin scaffold.

Step 9: The implantation of the ACI

The gel based ACI is a semi-liquid gel type mixture of cultured chondrocytes with thrombin and fibrinogen. It is implanted drop by drop on the restored bony defect. When the contents of both the syringes mixes and gets overlaid over the bony defect, a gel mixture is created containing chondrocytes and thrombin + fibrinogen that on solidification forms a 3-dimensional scaffold of fibrin with 3-dimensional equal distribution of chondrocytes throughout the lesion. The surgeon should be careful while implanting the gel drops as the drops may flow away from the prepared lesion. A gravity-controlled position of the defect is ideal but sometimes difficult to achieve in which cases, a dry gauze is kept toward the slope of the lesion to catch the drops. No material is used in between the bony bed and the ACI, as advocated in other techniques like the Sandwich technique.[9] It takes around 8 to 10 minutes for the gel based ACI implant to solidify and then a gradual range-of-movement is done to ensure proper implantation of ACI onto the prepared bony bed. Finally, the edges of the defect are checked to rule out any overflown gel and joint is checked for any gel remnants. The contour of the implanted ACI is checked for a good congruency (Fig. 7). A gentle normal saline wash is given taking caution that irrigation solution is not directly poured over the ACI. The closure is done in layer.

Step 10: Planning a rehabilitation protocol

The planning of a rehabilitation protocol after the overlay ACI technique can be quite challenging. The overlaid ACI does not change the rehabilitation protocol, but rehabilitation is dictated by the degree of bony involvement. Hence, the rehab protocol must be customized from patient to patient based on type of bony defect and the location of the bony defect resorted. General orthopedic principles of rehabilitation required for the restoration of a bony defect should be used, with equal weightage given to the combined ACI procedure. Essentially, the first phase of the rehabilitation should aim for 3 key areas: (1) protection of the osteochondral construct, (2) improving the range of the movements towards complete, and (3) maintaining the muscular strength. After 4 to 6 weeks, a dynamic muscle strengthening protocol should be added. Weight bearing decision and usage of braces, again depend on size and location of the restored bony defect. Use of contnuous passive mobilisation (CPM) machine is encouraged as with any ACI procedure.

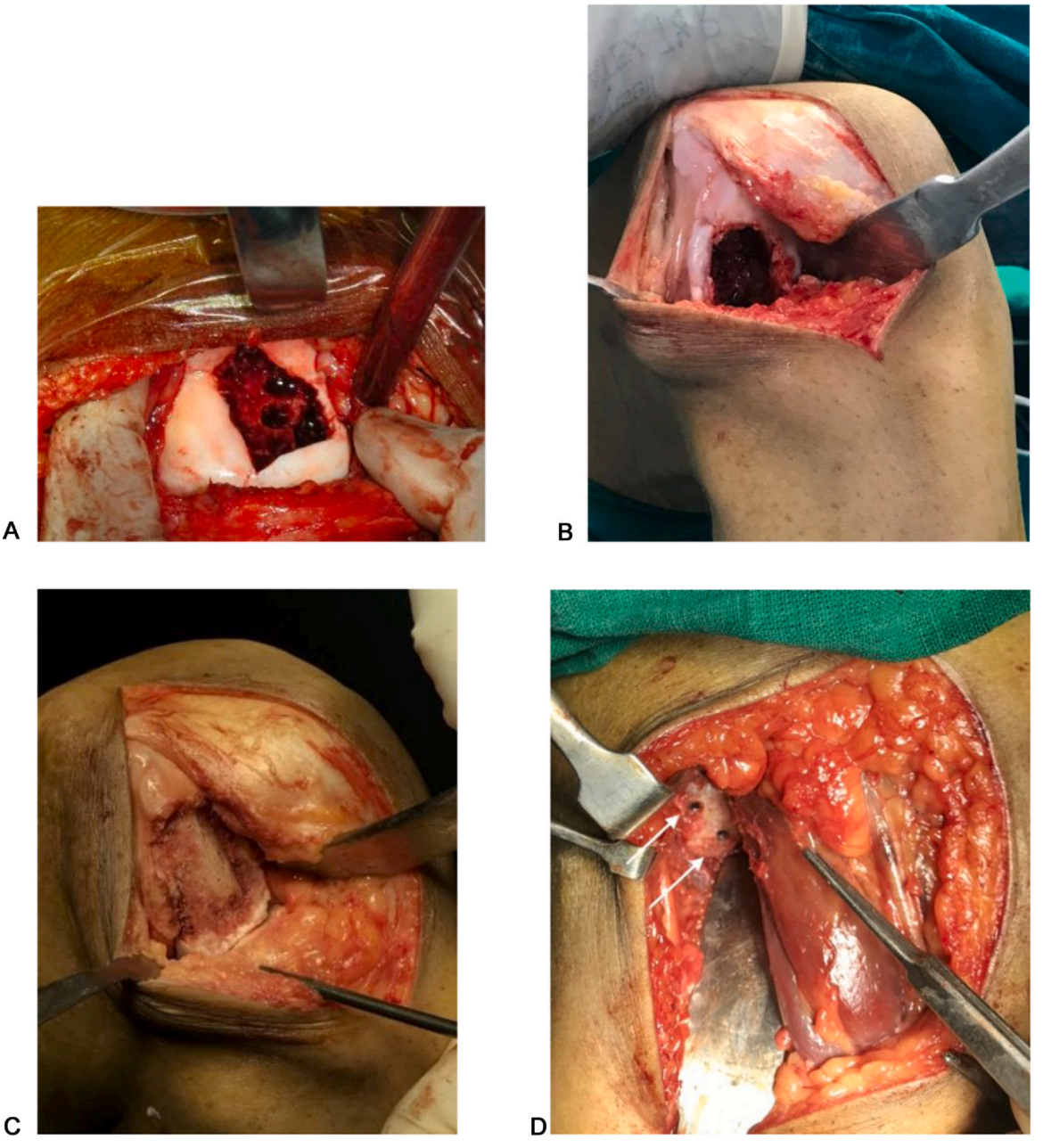

Fig. 5. **A**, A large area of denuded chondral surface of the trochlea with presence of multiple cysts that have been excavated till freshly bleeding margins. Such cysts can be filled with cancellous bone grafting and it should be packed till SC bone plate up to a level of surrounding intact SC bone plate. **B**, The large bony defect is seen in lateral femoral condyle where along with the large cartilage defect, the underlying SC bone plate and SC spongiosa were necrotic. After removing all the dead bone, a big cavity is created. However, the medial and lateral walls of lateral femoral condyle is still intact. **C**, A tricortical iliac crest graft with decorticated side walls is impacted into the defect of the lateral femoral condyle which press fits due to surrounding intact medial and lateral walls of the lateral femoral condyle. **D**, A tricortical iliac crest graft is fixed using 2 Herbert screws (white arrows) over the lateral femoral condyle using a popliteal approach. SC, subchondral.

The instruments

The routine instruments needed for any cartilage and bony surgeries are good enough for the Overlay ACI procedure. Small osteotomes and angled osteotomes, along with deep curettes are good enough to prepare the SC bone lesion (Fig. 9A). These instruments are needed for the preparation of bony bed, to clean the SC cysts, debride the SC lesion and scrap the lesion till a healthy SC bone. For the preparations of the cartilage lesion, different type of scoops and ring curettes, of different angles, are needed. A special

Table
Decision making for use of bone graft type based on the depth of the bony defect.

Final depth of the bony defect till healthy base	Type of graft
< 4 mm	No bone graft
4-8 mm	Cancellous bone graft (provided lesion is contained in majority of the sides)
> 8 mm	Tricortical graft with decorticated side walls

Fig. 6. A proprietary preparation method is used to prepare the final ACI implant in 2 different syringes which are connected by a "Y" connector. The first syringe contains 1 mL fibrinogen while the second syringe contains 0.9 mL of cultured chondrocytes and 0.1 mL of thrombin. Each drop coming out of a "Y" connector contains a mix of chondrocytes and thrombin-fibrinogen mixture that forms the fibrin scaffold.

trocar and cannula are advocated for use while taking a cartilage biopsy for ACI by the cartilage lab (Regrow Bioscience Pvt Ltd, India) (Fig. 9B). The trocar cannula set comes in 2 sizes, 7 mm and 4 mm, with 4 mm being the preferred size.

Discussion

The Overlay ACI technique,[7] is a promising technique to treat extra-large and large chondral lesions with big bony defects; as it takes care of the SC spongiosa, SC bone plate[10] as well as the cartilage. It is an established fact that SC bone is very essential for the health of the cartilage. The SC bone acts like a healthy soil to the cartilage by virtue of its load-bearing properties, nutritional role and a source of the healthy mesenchymal cells and the growth factors.[11] Normally, a healthy SC bone with lower elasticity absorbs much of the forces generated during the impulse loading, thus protecting the cartilage layer.[12] The anatomical and biomechanical functions of the articular cartilage and its supporting SC bone are hence tightly coupled with each other and therefore injury to either will adversely affect the entire joint environment.[13] It is also known that changes in SC bone may alter the biomechanical properties of the SC plate and thus influence the long-term survival of the repair tissue after different cartilage repair methods. This unique relationship between cartilage and underlying SC bone, makes osteochondral lesions a totally different entity from the pure chondral lesions. In the combined chondral and osseous lesions, the SC bone is either unhealthy or absent or pathological.[7] Hence, a simultaneous treatment of both the bony part and the cartilage part is a must; to restore the essential biomechanical environment between the SC bone and the cartilage. The regenerative cartilage tissue needs support from the healthy SC bone, otherwise the overlying cartilage repair will ultimately fail.

Large osteochondral defects are a big challenge not only to the surgeons,[1,4,13] but also for the society. It has a high morbidity rate at an early age along with a high health care cost.[1] The popular cartilage repair techniques like microfracture (MF), osteochondral

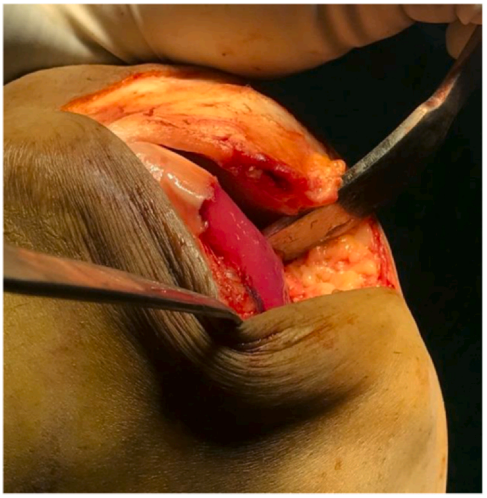

Fig. 7. A drop by drop gel based ACI is implanted over the prepared bony restoration (as in Fig. 5B and C). The gel based ACI fills the defect on the condyle and takes its contour, which further gets solidified in 8 to 10 minutes.

cylinder autograft transfer technique (OCT/OAT), ACI, and bone marrow aspiration concerntrate (BMAC) are recommended for the treatment of either a pure chondral lesion or for the treatment of a shallow and midsized osteochondral lesions; and these techniques cannot be used when there is a large chondral lesion with big bony defects. A systemic review of level II studies by Goyal et al[14] concluded that MF technique is only good for small cartilage lesions, at younger age group and for up to 5 years. Apart from its inability to treat large lesions, conventional marrow stimulation procedures cannot work in lesions with bone loss because these procedures require healthy bone marrow underneath as the source of pluripotent cells and healthy SC bone plate for the superclot to get adhered to. OCT technique can be used to treat osteochondral lesions as it replaces bony defect with an osseous cylinder and replaces cartilage with a hyaline chondral cap; however, the OCT technique has a size limitation, and it cannot be used to treat large lesions.[1,15] The ACI procedure requires autologous chondrocytes to be implanted over the healthy SC bone (preferably healthy SC bone plate) and hence ACI alone cannot address the underlying bony defect. If a bony defect is filled with ACI alone then the whole implantation can become unstable and can dislodge from the site.

There are a few techniques that are described in the literature for the treatment of combined osseous and chondral lesions, such as the sandwich technique, biphasic and multiphasic scaffolds and the osteochondral allografts. The sandwich technique was advocated by Peterson[16] and Brittberg[9] for the simultaneous treatment of chondral lesions with bony defects and has been further recommended by various authors.[9,17–19] However, there are only few studies about the technique in English literature, mostly small case series for the treatment of small to mid-size bony defects.[9,17–19] Ogura et al[20] published mean 7.8 years follow up of 15 patients treated with the sandwich technique and reported a very high satisfaction rate of 93%. Minas et al[18] compared results of sandwich technique with bone-grafting alone and reported a significant survival rate of 87% in sandwich group as compared to 54% in bone-graft group alone. One of the most significant difference between the overlay ACI technique and the sandwich technique is that the former technique does not use any intervening membrane or interface between bony restoration and ACI. Removal of the membrane between the 2 tissues saves extra skill and time needed to suture the membrane, improve reachability of the procedure to “difficult to reach areas,” expands scope of the procedure to much bigger lesions and also saves time for periosteal harvest if a periosteum is used as a membrane. Compared to the sandwich technique, the overlay ACI technique has been used to treat large to extra-large osteochondral lesions.[7] Allograft transfer for the large osteochondral technique is another good option and has shown encouraging results.[21] However, it is a reality that allograft is not accessible in all the countries including many developed countries. There are multiple regulatory issues and infrastructure issues. It also involves the high cost and has inherent vulnerability of transfer of unknown diseases. The best results of OC allografts were reported in younger patients (< 30 years) having unipolar, traumatic lesions with short duration of symptoms (< 12 months).[5] The overall resurgery rate after OC allografts has been published to be as high as 35%.[5] Biphasic and multiphasic scaffolds can be another option to deal with osseous and chondral defects simultaneously and size should not be an issue since these are produced synthetically. These scaffolds can provide different biological and functional environments for growth of 2 completely different tissues yet work as a single unit. However, all the research related to biphasic scaffolds largely remains restricted to animal studies,[22–25] except few studies on MaioRegen.[26] Few case reports using techniques like single stage bone grafting along with autologous matrix induced chondrogenesis,[10] bone marrow concentrate covered with collagen membrane[13] etc has also been recently described.

Könst et al[27] treated 9 patients of combined osteochondral defects, having mean defect size of 7.1 cm^2 and mean depth of 0.9 cm, with autologous bone grafting and gel based ACI without any intervening membrane. At mean follow up of 9 months, they reported good functional score outcome in 8 patients with 1 failure. The long-term MR-radiology (magnetic resonance radiology) results of a few cases of the overlay ACI technique have been reported in literature.[7] The reported cases have shown good healing of SC bone with

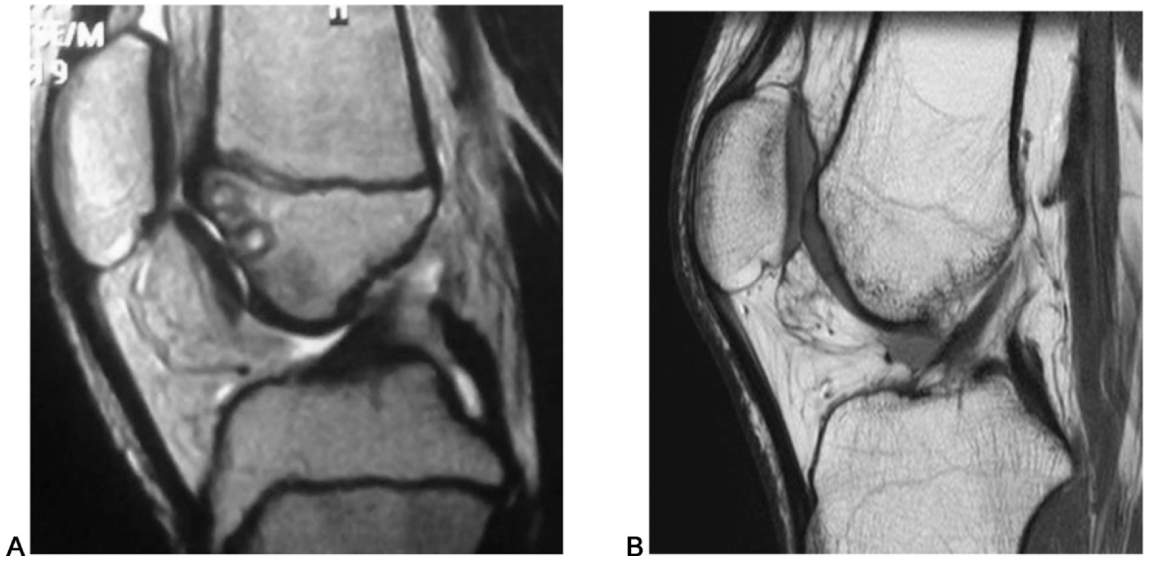

Fig. 8. **A**, An magnetic resonance imaging (MRI) of a 13 years old male patient suffering from huge osteochondritis dissecans of the trochlea, shows total separation of the large chondral piece from the trochlea. The separated piece also involves large SC bone plate and shows presence of multiple SC cysts in trochlear SC spongiosa bone. **B**, The operated overlay ACI patient for the same lesion as in (**A**) shows nice healing of the SC bone cysts along with complete restoration of SC bone plate at 8 years of follow-up. The chondral surface has also regenerated with homogenous regenerate, which is congruous and is well integrated with surrounding cartilage. SC, subchondral.

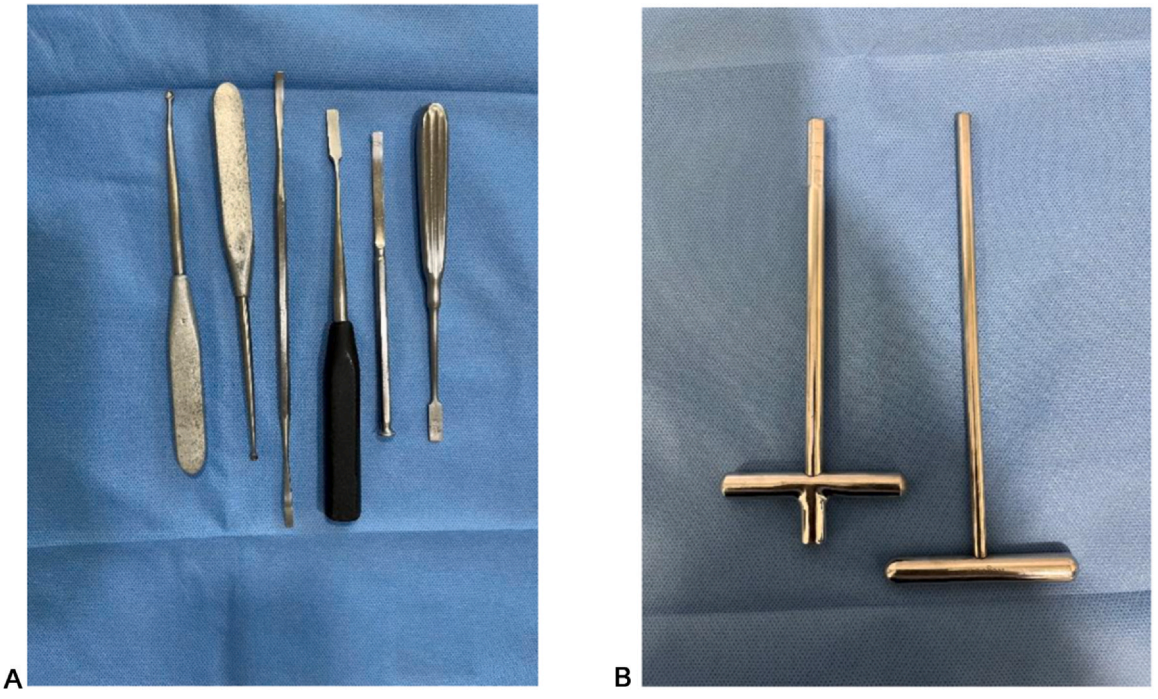

Fig. 9. **A**, Some basic instruments form the general orthopedic bone-grafting tray like small and angled osteotomes, deep curettes etc are enough instruments for the preparation of bony bed, to clean the subchondral (SC) cysts, debride the SC lesion and to scrap the lesion till a healthy SC bone. For the preparations of the cartilage lesion, different type of scoops and ring curettes, of different angles, are needed. **B**, A special trocar and cannula are advocated for use while taking a cartilage biopsy for ACI by the cartilage lab (Regrow Bioscience Pvt Ltd, India).

nice integration of SC spongiosa with the surrounding bone (Fig. 8A and B). The SC bone plate has also restored well, with good congruency and healing with surrounding bone plate. The overlaid ACI also showed homogenous regenerate with congruous surface and nice integration to surrounding cartilage.

The advantages, risks and limitations are discussed below.

Advantages of the overlay ACI technique

The overlay ACI technique offers several advantages as narrated below:

1. The overlay ACI technique is an autogenous alternative for the simultaneous osseous restoration and chondral reconstruction for the cases having large chondral lesions with big bony defects.
2. The technique is used exclusively to treat those cases, which are beyond the scope of a treatment using conventional methods like MF, OCT, ACI, BMAC, allografts, etc.
3. A nicely implanted bone graft ensures good restoration of the large bony defect, the skills and technology of which is native to any orthopedic surgeon. Similarly, the ACI is overlaid as per the standard procedure, the skill and technology of which is also native to any cartilage surgeon with a reasonable experience. Hence, any cartilage surgeon with good basic background of orthopedics can execute this procedure with required planning. As such, no extra training may be needed for the same.
4. A good long-term result[7] after the technique ensures restoration to normal/near normal anatomy with return to complete function. The cases, so far reported in literature[7,27,28] have shown nice restoration of SC spongiosa and SC plate with good regeneration of homogenous cartilage on the top of it.
5. Life expectancy of a restored bony defect with bone grafting is usually lifelong. Large bony defects treated by the overlay ACI technique should also be sustainable long term; however, this needs to be confirmed with long term data.

Risks involved in the overlay ACI technique

The overlay ACI technique has potential of high risks in the hands of unexperienced surgeons. Some of the risks are summarized below:

1. Even though the technique is described in a step wise manner, each case will require extensive customization based on the size, depth and the location of the lesions apart from other variables inherent to any cartilage treatment.
2. As large areas of SC bone spongiosa and SC bone plate are damaged in such cases, each case needs to be carefully assessed. Any unrealistic planning can lead to further loss of SC bone leading to poorer prognosis.
3. The surgeon should be careful while attempting bone graft into the large bony defect and should use his basic general orthopedic acumen to ensure good bone graft integration into the defect. If bone graft fails to integrate, there will be a much larger defect and added disability.
4. The surgeon must ensure a nicely reconstructed SC bone plate or bone graft bed for a proper overlay of ACI. Any sharp edges or uneven surface will make overlaid ACI unstable and then, ACI will fail.
5. The implantation of ACI is done at the same time, and thus it is crucial to use principles of bone grafting and ACI simultaneously but judiciously. A freshly bleeding bed of implanted bone grafting, an unstable bone graft into the defect will not allow overlaid ACI to survive.
6. Any complication that can occur after a bone-grafting procedure or after an ACI procedure can also occur after the overlay ACI procedure. The potential complications include, dislodgment of restored bone graft along with ACI graft, nonunion of bone graft, loose bone graft making ACI unstable, hypertrophied ACI, loose body from overgrown cartilage, failure of cartilage to regenerate, infection, etc.
7. The rehabilitation after the overlay ACI technique is tricky as it must protect 2 different types of tissues restored in 2 different manners. Each case requires customization by the surgeon himself, which must be communicated to physiotherapists personally.

Limitations of the overlay ACI technique

1. All the limitations of the current ACI technique used by the respective surgeon will also be the limitation of the overlay ACI technique. The technique will continue to depend on cartilage biopsy to be harvested as the index surgery before main surgery is planned.
2. The technique cannot be practiced at centers where ACI is not available.
3. Long term data of the technique is needed to assess survivorship of the technique.

Contraindications of the overlay ACI technique

1. The technique should not be used in the presence of inflammatory, metabolic, and rheumatic conditions.
2. A combined skill of cartilage surgeon and a general orthopedic surgeon is a prerequisite. Hence, the technique should only be performed by senior surgeons with enough experience in dealing with both types of tissues.
3. Any patient who is not ready for the long-term rehabilitation is not a good candidate for this technique.

Conclusion

The presence of large chondral lesions with big bony defects is a surgical joint preservation challenge. The overlay ACI technique is a promising technique to treat such extra-large osteochondral lesions. The technique combines principles of autogenous bone grating for the treatment of large bony defects, which is followed by an overlay of ACI in a conventional manner. Although a challenging surgery, the technique can potentially provide a long-term autogenous solution in form of a pain-free biological joint without any sequelae to the host tissue and formation of the hyaline (like) cartilage.

Ethics approval

The patient's personal information, videos, pictures used in this manuscript, if any, have been used after getting due informed consent from the patient.

Funding

No funding was received while preparing this manuscript or while performing the present study.

Authorship contributions

The author confirms that all the contents of this manuscript are written by himself. No one except him has contributed to writing this manuscript. There was no use of AI or equivalent technologies in writing this manuscript.

Declaration of Competing Interest

None.

Appendix A. Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jcjp.2024.100178.

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