Osteochondral Autograft “Plug” Transfer

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DEFINITION
- Osteochondral autograft “plug” transfer is a technique for treating full-thickness, localized articular cartilage lesions with or without subchondral bone loss in a nonarthritic joint.
- Cylinders or “plugs” of healthy cartilage, with their associated tidemark and subchondral bone, are harvested from one location in the joint and press-fit into same-length recipient holes previously prepared in the lesion to restore the bone and articular surface contour.
- Multiple plugs may be transferred to the same region, depending on the defect size.

ANATOMY
- Articular cartilage has a complex structure and plays a vital role in normal and athletic activity. It transmits load uniformly across the joint and provides a smooth, low-friction, gliding surface.
- Articular cartilage is a smooth, viscoelastic, hypocellular structure with a low coefficient of friction (estimated to be 20% of the friction seen with ice on ice) and the ability to withstand significant recurring compressive loads.
- The articular surfaces of diarthrodial joints are covered with hyaline cartilage.
- Hyaline cartilage is composed of sparsely distributed chondrocytes in a large extracellular matrix made up of about 80% water and 20% collagen.
- Collagen fibers provide form and tensile strength; water gives it substance.
- Type II collagen accounts for 95% of the total collagen present. The cellular component (chondrocytes) synthesizes and degrades proteoglycans and is the metabolically active portion of this structure.
- Articular cartilage has four distinct zones: a superficial (tangential) zone, a middle (transitional) zone, a deep (radial) zone, and the calcified zone (FIG 1).
- The superficial zone collagen fibers are oriented parallel to the joint surface and resist both compressive and shear forces. This zone is the thinnest and is sometimes called the gliding zone.
- The surface layer, known as the lamina splendens, is cell free and consists mainly of randomly oriented flat bundles of fine collagen fibrils.
- Under that layer are more densely packed collagen fibers interspersed with elongated, oval chondrocytes oriented parallel to the articular surface.
- This superficial zone acts as a barrier, limiting the penetration of large molecules into the deeper zone and preventing the loss of molecules from the cartilage into the synovial fluid.
- The middle (transitional) zone collagen fibers are parallel to the plane of joint motion and resist compressive forces.
- This zone has more proteoglycans and less water and collagen than the superficial zone.
- The chondrocytes are more spherical with more cellular structures, suggesting a matrix synthesis function.
- The deep (radial) zone fibers are perpendicular to the surface and resist both compressive and shear forces.
- The collagen bundles are arranged in a formation known as the arcades of Benninghoff, in which the round chondrocytes are arranged in columns perpendicular to the joint surface.
- The tidemark is located at the base of the deep zone and resists shear stress. It represents a zone of transition from the deep zone to the zone of calcified cartilage.
- The calcified zone acts as an anchor between the articular cartilage and the subchondral bone.
- It is the deepest zone and is a thin layer of calcified cartilage creating a boundary with the underlying subchondral bone.
- The cells in this zone usually are smaller and are surrounded by a cartilaginous matrix.

PATHOGENESIS
- Chondral damage can result from a variety of mechanisms, including a pivoting twisting fall, significant direct impacts on the knee, anterior cruciate ligament (ACL) tears, or a patellar dislocation (FIG 2).
ACL injuries may lead to instability and cause direct contusions to the articular surfaces and localized, full-thickness articular cartilage defects.

Osteochondritis dissecans (OCD) involves the separation of subchondral bone and cartilage from surrounding healthy tissues.

It most commonly occurs in the lateral aspect of the medial femoral condyle.

Traumatic osteochondral lesions include acute bone and cartilage loss due to fracture, crushing, or shear injuries.

Sometimes, even without a clearly remembered traumatic event, the patient develops pain with weight bearing.

**NATURAL HISTORY**

Cartilage biopsy samples overlying bone bruises have shown degeneration, necrosis of the chondrocytes, and a loss of proteoglycan.

An experimental model suggests that a severe bone bruise and its associated chondral necrosis are precursors to degenerative changes.

Instability secondary to ACL loss has been shown to contribute to the onset of osteoarthritis after ACL tears.

Articular cartilage has limited regeneration potential.

**PATIENT HISTORY AND PHYSICAL FINDINGS**

Full-thickness cartilage lesions are associated with various mechanisms of injury, including pivoting, twisting falls, direct impacts, and patellar instability.

Full-thickness chondral lesions are often clinically silent and should be suspected in the setting of any traumatic hemarthrosis, especially with a ligament disruption.

Reports of pain localized to one compartment, a persistent dull aching pain worsening after activity, and pain most noticeable when falling asleep are common.

Running, stair climbing, rising from a chair, and squatting may aggravate the symptoms, as does sitting for a prolonged period.

Physical findings include joint line tenderness, effusion, crepitus, grinding, or catching.

OCD has no exclusive physical findings. In the past, the Wilson sign was thought to be diagnostic of medial femoral OCD. This sign consists of producing pain by internally rotating the tibia during knee extension between 90 and 30 degrees of flexion and then relieving that pain by externally rotating the tibia. However, currently, Wilson sign is felt to be of little diagnostic value.

Effusion is nonspecific but suggests intra-articular pathology.

Pain on direct palpation of the femoral condyles may indicate cartilage damage.

Decreased range of motion is nonspecific but often indicates pathology.

The Lachman test detects ACL instability that may lead to cartilage injury.

Malalignment of the tibia to the femur when standing may lead to abnormal chondral wear.

A positive patellar apprehension test signals damage to the medial patellofemoral ligament.

**IMAGING AND OTHER DIAGNOSTIC STUDIES**

A standard radiographic knee evaluation should be performed.

This includes standing anteroposterior (AP) views in full extension to identify angular changes and to compare joint space height.

A 45-degree flexion posteroanterior (PA) weight-bearing view may identify subtle joint space narrowing.

A non–weight-bearing lateral view obtained in 45-degree flexion in which the posterior femoral condyles overlap, an axial view of both patellae to help evaluate the patellar alignment, and an AP knee flexion view to outline the femoral intercondylar notch also should be obtained.

OCD lesions are most commonly found in the lateral aspect of the medial femoral condyle and are best demonstrated on an AP knee flexion view.
Differential Diagnosis

- Partial- or full-thickness cartilage lesion
- Osteonecrosis
- OCD
- Meniscal tear
- Ligament injuries

Nonoperative Management

- Nonoperative treatment for full-thickness, discrete chondral lesions consists of physical therapy, anti-inflammatory medication, and activity modification to avoid high-impact or patella-destabilizing activities.
- Patellar stabilizing braces for patellofemoral instability and load-shifting braces that unload the injured compartment are options.
- Unloading the compartment can also be accomplished with shoe inserts that provide an appropriate heel and sole wedge.
- These efforts are more effective for medial femoral condyle lesions than lateral ones.
- It is important to ensure that the patient understands that full-thickness lesions have little spontaneous healing capacity and that further degeneration is likely.

Surgical Management

- The indications for osteochondral autograft plug transplantation include discrete, isolated, full-thickness articular cartilage lesions with good articular cartilage margins between 1.0 and 2.5 cm² (FIG 4).
- Acceptable results with larger defects have been reported but not consistently.
- If the depth of subchondral bone loss exceeds 6 mm, it will be necessary to lengthen the harvested plug accordingly to make up for the increased loss and effectively bone grafting the defect.
- Contraindications include opposing full-thickness articular cartilage damage (“kissing” lesions), multiple-compartment full-thickness lesions, significant angular changes, history of joint infection, intra-articular fracture, and rheumatoid arthritis.
- This technique is most commonly performed on the femoral condyle; however, osteochondral autograft transplantation of the trochlea, patella, tibial plateau, humerus, elbow, talus, and lunate has been reported.
- The COR Osteochondral Repair System (DePuy Mitek, Inc., Raynham, MA) allows for the no-impact harvesting of a precisely sized osteochondral autograft plug and the low-impact transplantation of the plug into a precisely drilled recipient site in the defect. The technique illustrated here uses this system.
- Key to the success of osteochondral autograft plug transfers is a perpendicular orientation of the plug in the recipient site. The COR osteochondral repair system has a unique perpendicularity guide which aligns the Harvester and then the inserter in the correct position.
- Other systems exist, including the Osteochondral Autograft Transfer System (OATS; Arthrex, Naples, FL) and Mosaicplasty (Smith & Nephew Endoscopy, Andover, MA).
- Significant technical differences exist in these systems.

Preoperative Planning

- The success of this procedure depends on maintaining viable chondrocytes. Various studies confirm that greater pressure on the articular cartilage cells leads to cell death. Several technical issues are related to greater transplanted cell death. These include high-impact pressure during insertion, proud grafts which are not advanced to the level of the adjacent native articular cartilage, and sunken grafts depressed 2 mm or more compared to the adjacent articular cartilage.
- The ideal technique optimizes graft position and stability, provides for consistent graft length harvesting, and minimizes the forces required to insert the grafts.
- Other procedures can be performed at the same time as osteochondral autograft plug transfer, including meniscal repair, osteotomies, and ligament reconstruction.
- Improved results in unstable knees occur with concomitant ACL reconstruction.
- Any ligament instability or malalignment should be corrected at the time of autografting to avoid increased failure rates.
- Radiograph and MRI studies should augment the arthroscopic assessment of the lesion to confirm the decision whether an arthroscopic or open approach is required.
Perpendicular placement of the harvester and drill to the articular surface is required.

The COR transfer system has a unique “perpendicularity” guide which enhances the perpendicular harvest of the donor graft as well as the perpendicular orientation of the drilled recipient site.

If the potential use of allograft material is suspected, it should be available in the operating room before surgery begins.

Although allograft tissue avoids the issue of harvest site morbidity, it is offset by the risks of transmitted disease and decreased chondrocyte viability and results in significantly increased cost.

**Positioning**

- Osteochondral autograft transfer in the knee is performed with the patient supine and the operative knee in an arthroscopic leg holder flexed off the table.
- It is crucial to confirm that the knee can be flexed adequately to access the lesion before operative preparation and draping. This may require placing the leg holder more proximal than usual. The ability to flex the knee to at least 100 degrees is preferred.
- The contralateral leg should be well padded and positioned out of the operative field.
- It may be necessary to drape the operative leg free of a leg holder to obtain enough knee flexion to access the lesion.
- A tourniquet is not recommended. Using hypotensive anesthesia and an arthroscopic technique, clear visibility is easily achieved. The lack of an inflated tourniquet allows for the confirmation of good vascularity in the donor site and a better assessment of the bone viability in the adjacent area.

**Approach**

- Arthroscopic osteochondral autograft plug transplantation can be technically challenging. The need to achieve perpendicular access to the lesion and the articular cartilage donor site while holding the knee at the appropriate degree of flexion requires a team approach.
- We prefer a central (transpatellar tendon) viewing portal, although the contralateral anterior lateral or anterior medial portal work as well.

- Three donor sites are available: the superior lateral intercondylar notch, the superior medial trochlea, and the superior lateral trochlea above the linea terminalis.
- The superior lateral intercondylar notch donor site allows ready arthroscopic access and reduces the need for an arthrotomy.
- The superior medial trochlea above the linea terminalis offers a donor site with the least pressure during knee loading. It can be readily accessed by simply extending the knee while viewing through the central portal and instrumenting through the anterior medial portal.
- The superior lateral trochlea above the linea terminalis sees the highest pressures of these three donor sites. It is the most difficult to access arthroscopically because of the lateral position of the patella. A separate arthroscopic incision is often required to harvest from this area.
- A thorough arthroscopic diagnostic knee evaluation should be performed first.
- A spinal needle can be used to determine the best angle for portal creation, ensuring a perpendicular approach to the harvest and defect sites. If required, an arthrotomy can be performed for lesions that cannot be addressed adequately by arthroscopy.
- Arthroscopic osteochondral autografting includes five steps: lesion evaluation and preparation, determination of the number of grafts needed, defect preparation, graft harvest, and graft delivery.
- The other autograft plug transfer systems’ techniques differ in key ways including the order in which the donor plugs are harvested and the relative length of the donor plug to the recipient hole.
- The Mosaicplasty system underdrills recipient site by 2 mm to create room for debris and allowing the graft to “float” into place. The donor plug is harvested first. Once the actual length of the graft is confirmed, the recipient hole is created. In this way, a donor–recipient site mismatch is avoided.
- The OATS system underdrills the recipient sites by 2 mm and requires a final “impaction” of the longer graft to improve graft stability. However, this impaction places high-impact pressures on the graft’s articular cartilage. Here, too, the donor plug is harvested first before creating the recipient hole to avoid donor–recipient site mismatch.

**Diagnostic Arthroscopy**

- After a review of any radiographic and MRI studies, a diagnostic arthroscopic evaluation is conducted. A complete examination of all areas of the knee must be performed before proceeding further to identify any other pathology and confirm that no contraindications to the procedure exist.
- As with all diagnostic arthroscopic knee examinations, it is necessary to look in the posterior medial recess, the posterior lateral recess, and underneath both menisci for chondral pieces.
- Concomitant ligament surgery should be performed after the osteochondral autograft transplantation.
- An adequate synovectomy, especially of the fat pad, is needed to facilitate complete visualization of both the defect and harvest sites.

**Lesion Evaluation and Preparation**

- A 14-gauge Jelco needle can be used to identify the correct portal placement and alignment for a perpendicular approach to both the defect and donor sites before the portal is created.
- The defect is prepared by removing loose debris and freshening the edges with a curette or an arthroscopic knife to create perpendicular chondral walls (TECH FIG 1).
- The subchondral bone should be cleared of any residual articular cartilage, but generalized bone bleeding should be avoided.
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TECH FIG 1  ● The defect is prepared by removing loose debris and freshening the edges with a curette or an arthroscopic knife to create vertical chondral walls.

**TECHNIQUES**

- **Determining Number of Grafts**
  - The number of grafts required is planned using the probe to obtain a preliminary measurement of the defect's shape and dimensions (**TECH FIG 2A**).
  - When using more than 1 graft, a 2- to 3-mm bone bridge should be maintained between the recipient sites to ensure a good press-fit. The femoral condyle surface is rounded. Placing the bone plugs closer together will result in the plugs intersecting below the articular surface, making graft insertion more difficult and possibly extruding a previously placed plug.
    - Proud graft placement should be avoided at all costs. The transplanted articular surface will be irreversibly damaged by subsequent weight bearing leading to fissuring, fibroplasia, and subchondral caviation.
    - A sunken plug 2 mm or greater leads to articular cartilage necrosis and fibrous overgrowth.
  - The depth of the lesion (existing bone loss) can be estimated using the 2-mm marks on the side of the harvester.
  - A series of grafts 6 mm in diameter fills the defect best. Grafts 8 mm in diameter can be used as an alternative.
    - Larger plug harvesters are available but may require an arthrotomy and are more likely to encroach on weight-bearing areas at harvest sites.
    - Specifically, given that a 10-mm diameter lesion is an indication for grafting, harvesting a 10-mm graft defeats the purpose of using this grafting technique. It makes little sense to create such a lesion in an attempt to plug another one.
    - The plan should be to place the grafts starting at the periphery of the defect so that the articular cartilage matches the adjacent chondral edge after transplantation (**TECH FIG 2B**).
  - The defect depth must be considered when harvesting the plugs.
    - In most cases, advancing the harvester to the 12-mm depth provides sufficient bone.
    - OCD lesions or those with significant bone loss may require longer bone plugs, which usually vary between 15 and 20 mm in length. Referring to the appropriate laser mark on the harvester will create graft plugs with the proper length.

- **Defect Preparation**
  - Any residual articular cartilage is removed from the subchondral bone surface, but generalized bone bleeding should be avoided.
  - Using the COR perpendicularity system in the drill guide sleeve reproducibly achieves the best drill orientation at the recipient site.
  - The recipient site should be drilled before harvesting the graft plugs.
  - Drilling the recipient site before harvesting the donor autograft plugs allows the best contour match to the femoral surface between the donor grafts and the articular cartilage adjacent to the recipient sites.
Graft Harvest

- Potential donor harvest sites include the lateral and medial trochlea above the linea terminalis and the superior lateral intercondylar notch.
  - In general, contact pressures are lower in the intercondylar notch and medial trochlea, but available harvest material is limited.
  - Higher contact pressures are found in the lateral trochlea, but these decrease more posteriorly.
  - Harvesting 5-mm plugs from the lateral trochlea did not result in significant increases in stress concentration and loading in one study.7
  - We prefer to harvest from medial trochlea above the linea terminalis or the superior lateral intercondylar notch because both allow ease of access for a totally arthroscopic technique (TECH FIG 4A).
- Once the number of plugs to be obtained is determined and the sites prepared, the harvester is inserted into the disposable cutter.
  - The retropatellar fat pad is completely débrided to improve visualization and avoid soft tissue entrapment.
  - The COR Harvester Delivery Guide comes with the cutting tool preassembled as a single unit. The perpendicularity rod should be inserted into this Harvester/Cutter assembly before insertion into the joint. The perpendicularity rod will function as an obturator and minimize both soft tissue capture and fluid loss as the assembly is inserted into the knee.
  - The Harvester Delivery Guide/Cutter/perpendicularity rod assembly is positioned on the donor site in preparation for the graft harvest. The perpendicularity rod is used to confirm the perpendicular position of the cutter and then removed.

- The arthroscope is rotated to view the Cutter from different angles and confirm that the alignment is correct.
  - Perpendicular grafts can be obtained readily with both arthroscopic and open approaches.4
  - While continuing to hold the harvester perpendicular to the articular cartilage in all planes, use a mallet to tap the Harvester Delivery Guide/Cutter to the desired depth based on the 5-, 8-, 10-, 12-, 15-, and 20-mm laser markings on the side of the harvester (TECH FIG 4B).
    - A unique feature of the COR system is the cutter tooth on the distal harvester edge, which underscores the cancellous bone at the distal end of the harvester tube, allowing for a precise and consistent depth of cut (TECH FIG 4C).
    - The T-handle of the harvester is rotated clockwise at least two full rotations, undercutting the distal bone and achieving the desired harvest depth.
  - The plug is removed by gently twisting the T-handle while withdrawing the plug. Care should be taken to avoid toggling the donor hole, which will widen and deform it.
  - On a firm surface, insert the Harvester Delivery Guide/Cutter into the graft loader and push down firmly until it makes contact with the bottom of the loader. The harvested graft will be pushed from the cancellous bone side of the graft plug upward into the Harvester/Delivery Guide and out of the cutter section (TECH FIG 4D). A loud noise usually accompanies this transfer.
  - The harvester is removed from the cutter. The graft plug has been transferred and remains inside the harvester until it is transplanted.
  - This transfer system totally avoids any compression load on the articular surface of the graft and eliminates the danger of chondrocyte damage in this step.
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TECHNIQUES

A. Harvest sites include the superior and lateral intercondylar notch, an area that is commonly removed in ACL reconstruction notchplasty. B. Position the Harvester/Delivery Guide/Cutter with the perpendicularity guide on the selected donor site. After verifying the perpendicularity, remove the guide and then tap the harvester until the desired laser line depth has been reached. C. A unique feature of the COR system is the cutting tooth which underraces the cancellous bone at the distal end of the harvester tube and allows for a precise depth cut. D. On a firm surface, insert the Harvester/Delivery Guide/Cutter into the graft loader and push down firmly until it makes contact with the bottom of the loader. The harvested graft will be pushed from the cancellous bone side of the graft plug upward into the Harvester/Delivery Guide and out of the cutter section. (B,C: Courtesy of DePuy Mitek, Inc., Raynham, MA.)

TECH FIG 4

Graft Insertion

- Once the harvester tube is disassembled from the cutter, the graft and articular cartilage cap orientation can be assessed through the clear plastic and the length measured using the markings.
- The plastic plunger is placed in the harvester delivery system before insertion of the delivery system into the joint.

- The loaded harvester–clear plastic delivery guide system is then inserted into the knee. It may be necessary to enlarge the portal slightly to permit this passage.
- The clear end of the delivery system allows a good view of the graft. With the graft plug at the very end of the clear delivery tube, align it with the recipient site outlet and the adjacent articular cartilage. Advance the plug into the recipient site by gently
tapping the blue plunger until the graft is flush with the adjacent articular cartilage surface (TECH FIG 5).

- The Universal tamp may be used to fine-tune the graft placement.
- The 8-mm side of the Universal tamp is recommended for 4- and 6-mm grafts and the 12-mm side is recommended for 8- and 10-mm grafts.

**TECH FIG 5**  The harvester–clear plastic delivery guide system loaded with the autograft plug is held perpendicular to the articular cartilage and implanted with gentle tapping on the blue plunger.

- **Multiple Graft Repair**
  - If more than one graft is needed to repair an articular cartilage defect, the Harvester/Delivery Guide and Cutter is reassembled and the process repeated until the defect is completely filled. A 2- to 3-mm bone bridge should be maintained between the drilled holes to allow for a secure graft press-fit.

- **Backfilling**
  - Filling the donor sites is recommended, especially for harvested plugs greater than 6 mm in diameter or if multiple plugs have been harvested from a single area.
    - Large diameter and deep defects can cause excessive stress on the surrounding cartilage and lead to degeneration.\(^{13}\)
    - Allograft material can be used to accomplish this backfill if desired (TECH FIG 6).

**TECH FIG 6**  Grafting the donor sites is recommended, especially for multiple harvested plugs greater than 6 mm in diameter from a single area. Cancellous allograft croutons or cylindrical plugs can be pressed into the donor sites.

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**PEARLS AND PITFALLS**

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<th>Indications</th>
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| Associated instability and malalignment must be addressed.  
| Proper patient selection is the key to good results.  
|  
| Lesion preparation |  
| Remove loose debris and freshen the lesion’s edges with a curette to create vertical chondral walls.  
| The subchondral bone should be cleared of any residual articular cartilage, but generalized bleeding should be avoided.  
|  
| Graft harvesting/implantation |  
| Rotate the harvester and do not toggle it when removing plugs to avoid damaging or expanding the donor site walls.  
| Inserted plugs should never be left proud under any circumstances. If a plug is “angled” in relationship to the surrounding cartilage, the plug should be sunk so that the upper edge of the graft is flush with the surrounding surfaces.\(^{16}\)  
| Minimize the force used during graft transfer and insertion to decrease articular cartilage cell death.  
| Place multiple graft plugs slightly separated or adjacent to each other. Overlapping plugs significantly decreases plug stability.  
| “Proud” graft |  
| If the graft is more than 0.5-mm proud, apply gentle taps with the tamp to advance it flush to the adjacent articular cartilage.  
| Removing and replacing a graft greatly diminishes graft stability.\(^{17}\) If the graft is markedly proud and cannot be salvaged, consider replacing with another graft.\(^{17}\)  

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POSTOPERATIVE CARE
- Immediate range-of-motion exercises without a brace are begun.
- Non-weight bearing is observed for 3 weeks, followed by progressive weight bearing during weeks 3 to 6 after surgery and then full weight bearing beginning at 6 weeks after surgery.
- A progressive quadriceps strengthening program should begin immediately postsurgery and advanced with full weight bearing.
- Full athletic activity is permitted at 4 months.

OUTCOMES
- Femoral condylar lesions typically have excellent clinical results.
  - Multiple authors report excellent and good results ranging from 78% to 96% at a minimum of 2 years follow-up.6,8,20,21
- Patellar or patellar and trochlear autograft plug transfers have been reported to have good to excellent results in 79% of patients.11,21
  - Allograft has been shown to be an effective treatment for patellofemoral disease.10,22
- Osteochondral autograft plug transplantation provides better long-term results than microfracture, Pridie drilling, and abrasion arthroplasty.8,10
- Osteochondral transplantation consistently results in restoration of hyaline cartilage versus “hyaline-like” or fibrocortilage seen with microfracture or autologous chondrocytes transfer.2,3,6,12
- Patients younger than 40 years of age have better results.6,9,20
- Insertion pressure on the plugs has a significant consequence to articular cartilage viability.
- Impacting plugs significantly lowers cartilage cell viability.15
- Patients treated with autograft plug transfers maintain higher athletic activity levels than those treated with microfracture.1,18

COMPLICATIONS
- Infection
- Loose body if graft loosens
- Graft reabsorption
- Cartilage degeneration due to excessive pressure when seating the graft
- Proud graft leading to excessive contact pressures, graft destruction, and possible “catching” sensation

REFERENCES