Metrics of OsteoChondral Allografts (MOCA) Group Consensus Statements on the Use of Viable Osteochondral Allograft

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Background: Osteochondral allograft (OCA) transplantation has evolved into a first-line treatment for large chondral and osteochondral defects, aided by advancements in storage protocols and a growing body of clinical evidence supporting successful clinical outcomes and long-term survivorship. Despite the body of literature supporting OCAs, there still remains controversy and debate in the surgical application of OCA, especially where high-level evidence is lacking.

Purpose: To develop consensus among an expert group with extensive clinical and scientific experience in OCA, addressing controversies in the treatment of chondral and osteochondral defects with OCA transplantation.

Study Design: Consensus statement.

Methods: A focus group of clinical experts on OCA cartilage restoration participated in a 3-round modified Delphi process to generate a list of statements and establish consensus. Questions and statements were initially developed on specific topics that lack scientific evidence and lead to debate and controversy in the clinical community. In-person discussion occurred where statements were not agreed on after 2 rounds of voting. After final voting, the percentage of agreement and level of consensus were characterized. A systematic literature review was performed, and the level of evidence and grade were established for each statement.

Results: Seventeen statements spanning surgical technique, graft matching, indications, and rehabilitation reached consensus after the final round of voting. Of the 17 statements that reached consensus, 11 received unanimous (100%) agreement, and 6 received strong (80%-99%) agreement.

Conclusion: The outcomes of this study led to the establishment of consensus statements that provide guidance on surgical and perioperative management of OCAs. The findings also provided insights on topics requiring more research or high-quality studies to further establish consensus and provide stronger evidence.

Keywords: articular cartilage; osteochondritis dissecans; allografts; osteochondral allograft

The popularity of fresh osteochondral allograft (OCA) transplantation has increased substantially over the past decade given its long-term success, with survivorship of ~90% at 5 years and ~75% at 10 years.[8,11] Several decades of translational studies have helped identify appropriate patient indications,[#] improve graft storage and processing,[28,62-64] and provide a body of literature reporting successful clinical results and long-term graft survivorship in patients treated with OCAs.[**] Despite the current evidence supporting its use, there remain areas of controversy and debate in the nuances of OCA application. Parameters of patient selection, contraindications, surgical technique, graft matching procedures, and rehabilitation protocols vary within the orthopaedic community. The current literature lacks quality evidence and comparative studies. Given these limitations and the lack of standardization across the clinical community, it is important to establish consensus on issues surrounding OCA transplantation of the knee.

It has been shown that, in the absence of consistent and objective conclusions from the literature, consensus criteria can be established by leveraging expert opinion and clinician experience through a Delphi approach. This type of process has been reported for various treatment/management controversies in the field of orthopaedics.[18,51,72] A group of the most highly experienced surgeons (experts), selected for their contribution to the science and clinical

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[#]References 1, 5, 6, 14, 17, 21, 29, 32, 36, 79.
[**]References 3, 13, 22, 23, 31, 37, 47, 52, 54, 59, 65, 67, 87.

application of OCA, was assembled to identify and address areas of standards of care and controversy in OCA surgery and subsequently develop consensus statements through the Delphi method. The goal of this process was to establish evidence-based consensus statements regarding indications, surgical technique, graft matching, and rehabilitation and return-to-sport recommendations. The level of consensus and evidence in these categories were analyzed to provide guidance where data were inconclusive and to identify areas that would benefit from further research to improve knowledge and quality of evidence. The aim was to assist clinicians in making decisions involving OCA transplantation application and patient care.

METHODS

Modified Delphi Method

A focus group of 23 experts was convened in 2018 to address controversies and identify areas of research opportunity for various clinical, scientific, and technical aspects of OCA transplantation. The expert group included the highest-volume surgeons, all performing >30 OCA transplantations per year (JRF Ortho Tissue Bank data) and all previously selected to participate in the Metrics of Osteo-Chondral Allografts (MOCA) Committee based on contributions to the science of OCA. MOCA is a working group dedicated to improving OCA restoration through outcomes

and translational research. The group identified 4 main topic areas in an effort to address unanswered clinical discrepancies in the literature and questions among the clinical community for OCA cartilage restoration: (1) indications, (2) surgical technique, (3) graft matching, and (4) rehabilitation and return to sport. A modification of the Delphi method, with 3 rounds of voting, was used to develop the consensus statements and establish agreement among the group.[50] The level of consensus was measured for each statement and defined as follows: consensus, 66.6% to 79%; strong consensus, 80% to 99%; and unanimous consensus, 100%. Details of the modified Delphi process are outlined in the Appendix.

Systematic Literature Search

A comprehensive systematic literature search was conducted to determine the level of evidence (LOE) of the supporting literature. PubMed/MEDLINE were reviewed from inception to April 2019. A general search strategy was followed by specific search terms using defined inclusion/exclusion criteria to screen and identify supporting peer-reviewed articles for each topic area of the generated consensus statements (Appendix). In total, 75 articles were identified that addressed OCA procedures and/or use of the Delphi method in the orthopaedic literature. These were used as the basis to construct the first round of questions and were then linked to support each statement as appropriate.

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	Round 1	Round 2	Round 3
Statements at start of round	14	29	25
New or modified statements	15	2	13
Statements removed or combined	0	4	8
Responses	23/23	21/23	18/23

Quality of Statements

The quality and grade of each statement were evaluated by measuring the LOE using the Centre for Evidence-Based Medicine's LOE and grades of recommendation. Two authors (S.G., S.M.T.) independently reviewed the LOE and grade for each statement and resolved any differences. The LOE and grades of recommendation are described in the Appendix.

RESULTS

Delphi Process Results

The 23 experts completed round 1 of the Delphi process (100% response rate), consisting of statements addressing key and/or empirically controversial areas in osteochondral allografting. After round 1 voting, the comments were summarized, and 15 additional statements were included in the round 2 survey; responses were requested within a 2-week time frame. A total of 21 experts completed round 2 of the survey within this time frame (91% response rate). The outcomes of round 2 led to the modification of 2 statements and the removal of 4 redundant statements. The final round was completed by 18 experts, who attended the 2018 MOCA meeting in person or participated remotely via mobile app (78% response rate) (Table 1).

Comments from committee members were used to modify preliminary statements or add new statements in round 2, to find common ground. In round 3, statements were again modified or culled to remove redundancy or overlap in ideas. Of the 25 preliminary statements voted on during the final round, 13 were modified and 8 were tabled. Of the 17 statements that reached consensus, 11 received unanimous agreement (100% agreement) and 6 received strong agreement (80%-99% agreement). The percentage of agreement and level of consensus for the final statements by category (indications, surgical technique, graft matching, and rehabilitation and return to sport) are summarized in Table 2.

Indications for Osteochondral Allografting

Level and Grade of Evidence. In the indications category, 5 statements reached strong or unanimous consensus. Of these statements, 1 was supported by level 2, level 3, and level 4 studies, and 3 statements were supported by level 3

and/or level 4 studies (grade C). One statement was expert opinion of the focus group (grade D) (Table 3).

Evidence Summary. The efficacy of OCAs for the treatment of osteochondral lesions is well established in the clinical community and supported by a substantial body of literature. Numerous studies have evaluated OCAs for various indications.[††] All experts of this focus group concurred that symptomatic osteochondral defects secondary to trauma, osteochondritis dissecans (OCD), osteonecrosis, and intra-articular fractures are appropriately treated with OCA. A recent systematic review demonstrated improved patient-reported outcomes and a mean survival rate of 78.7% at 10 years in OCAs of the knee for traumatic and degenerative chondral lesions, OCD, steroid-associated and spontaneous osteonecrosis, and osteoarthritis.[23] It was the unanimous consensus that contraindications include uncorrected ligamentous instability, uncorrected contributory malalignment, and advanced osteoarthritis, except in rare instances as a bridging procedure. This is supported by literature demonstrating higher failure rates of OCAs in patients with uncorrected limb malalignment and advanced osteoarthritis.[30,36,44,55,57,71] Additionally, a histological analysis of retrieved failed OCAs revealed a high presence of inflammatory cells and mediators associated with systemic inflammatory diseases in early and late failures of OCAs.[36]

Although there is a lack of consensus in the clinical community on surgical treatment algorithms for OCD,[67] the study participants strongly agreed (94%) that OCAs can be a primary treatment option for OCD. This result aligns with a number of studies that demonstrate improved patient outcomes, return to sport, and >90% graft survivorship at 5 years for treatment of OCD with fresh OCAs.[8,22,27,52,67,78] Specifically, Sadr et al[67] and Emmerson et al[22] demonstrated 95% and 91% graft survivorship at 5 years and 93% and 76% at 10 years, respectively. A recent study evaluating the association between patient satisfaction and clinical outcomes of patients treated with OCA showed a high and predictable satisfaction rate (95.6%) associated with outcomes for patients who underwent OCA for OCD.[78]

Additionally, a robust body of literature supported the statement that OCAs can be used to revise previously failed cartilage restoration procedures.[17,32,34,39,46,56,76,86] Of these studies, a comparison of outcomes after primary OCA versus revision OCA after a failed cartilage procedure showed no significant difference and similar survival rates between the 2 cohorts.[32,39,56] A recent systematic review investigating outcomes of revision cartilage restoration procedures demonstrated that revision OCA consistently had similar results to primary OCA transplantation, even if the subchondral bone was affected.[46]

Surgical Technique

Level and Grade of Evidence. The surgical technique category consisted of 5 statements that reached consensus and were graded as C or D (Table 4). Four statements were

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[††]References 8, 17, 21, 29, 35, 48, 52, 59, 65, 67, 71, 77, 79.

TABLE 2
Percentage of Agreement and Level of Consensus for Final Statements by Category[a]

Statement	Agreement, %	Level of Consensus
Indications		
OCA indications include symptomatic cartilage defect(s), including defect(s) secondary to trauma, OCD, osteonecrosis, intra-articular fractures in patients of any age, and activity level not suitable for prosthetic replacement.	100	Unanimous
Relative contraindications for OCA use include uncorrected ligamentous instability, uncorrected malalignment, and end-stage osteoarthritis except in rare instances where used as a bridging procedure.	100	Unanimous
OCAs can be used to revise previously failed cartilage restoration procedures.	100	Unanimous
OCAs can be considered a primary treatment for reconstruction of OCD lesions.	94	Strong
Systematic autoimmune/inflammatory joint disease is not an absolute contraindication to OCA implantation.	100	Unanimous
Surgical technique		
Supplemental fixation of an OCA is needed only if the graft is unstable.	94	Strong
Cysts beneath a lesion being restored with an OCA should be addressed by curettage and bone grafting.	100	Unanimous
The ideal depth of a femoral OCA recipient site is 6-10 mm.	100	Unanimous
The osseous component of OCAs should be pulse lavaged with sterile irrigation fluid with or without antibiotics before implantation.	94	Strong
It is unknown if OCA bone incorporation can be enhanced by biologic adjuncts.	94	Strong
Graft matching		
A contralateral graft is an OCA from the opposite condyle (eg, a lateral condyle for a medial condylar procedure).	89	Strong
A contralateral OCA can be utilized for single-plug restoration up to 25 mm in diameter.	100	Unanimous
Femoral condylar OCAs can be adequately size matched using condylar and/or tibial width measured on radiographs with magnification marker or magnetic resonance imaging/computed tomography.	96	Strong
A standardized method for testing cartilage viability and metabolic activity should be established.	100	Unanimous
Rehabilitation and return to sport		
An initial period of partial weightbearing (up to 6 weeks) for tibiofemoral OCA reconstructions is appropriate.	100	Unanimous
Weightbearing as tolerated in conjunction with extension bracing (up to 6 weeks) after patellar and/or trochlear OCA reconstructions is appropriate.	100	Unanimous
Time (minimum 12 weeks from surgery) and functional recovery should both be used as criteria to return to impact activities.	100	Unanimous

[a]OCA, osteochondral allograft; OCD, osteochondritis dissecans.

TABLE 3
Level of Evidence and Grade of Evidence for Indications for OCA[a]

Statement	Level of Evidence (No. of Studies per Level)						Grade of Evidence
	1	2	3	4	5	Total	
OCA indications include symptomatic cartilage defect(s), including defect(s) secondary to trauma, OCD, osteonecrosis, intra-articular fractures in patients of any age, and activity level not suitable for prosthetic replacement.[b]	0	1	1	37	0	49	C
Relative contraindications for OCA use include uncorrected ligamentous instability, uncorrected malalignment, and end-stage osteoarthritis except in rare instances where used as a bridging procedure.[c]	0	0	0	12	0	12	C
OCAs can be used to revise previously failed cartilage restoration procedures.[d]	0	0	3	8	0	11	C
OCAs can be considered a primary treatment for reconstruction of ODC lesions.[8,22,27,52,67,78]	0	0	1	5	0	6	C
Systematic autoimmune/inflammatory joint disease is not an absolute contraindication to OCA implantation.	0	0	0	0	0	0	D

[a]OCA, osteochondral allograft; OCD, osteochondritis dissecans.
[b]References 3, 5, 6, 8, 12–17, 19, 21–24, 27, 29, 31–33, 35, 37, 42, 45, 47–49, 52, 54, 55, 57, 59, 60, 65, 67, 68, 71, 77, 79, 87.
[c]References 3, 30, 36, 40, 44, 48, 49, 55, 57, 65, 70, 71.
[d]References 2, 17, 26, 32, 34, 39, 46, 56, 66, 76, 86.

expert opinion or supported by basic science studies (grade D), and 1 of the 5 statements was supported by level 3, level 4, and level 5 studies (grade C).

Evidence Summary. Although the surgical technique statements were limited by clinical evidence, fixation of unstable grafts and the surgical management of

TABLE 4
Level of Evidence and Grade of Evidence for Surgical Technique[a]

Statement	Level of Evidence (No. of Studies per Level)						Grade of Evidence
	1	2	3	4	5	Total	
Supplemental fixation of an OCA is needed only if the graft is unstable.	0	0	0	0	0	0	D
Cysts beneath a lesion being restored with an OCA should be addressed by curettage and bone grafting.	0	0	0	0	0	0	D
The ideal depth of a femoral OCA recipient site is 6-10 mm.[4,86]	0	0	0	1	1	2	D
The osseous component of OCAs should be pulse lavaged with sterile irrigation fluid with or without antibiotics before implantation.[4,38,41,75,81]	0	0	0	0	5	5	D
It is unknown if OCA bone incorporation can be enhanced by biologic adjuncts.[61,74,85]	0	0	1	1	1	3	C

[a]OCA, osteochondral allograft.

subchondral cysts beneath surface lesions were critical technical considerations that may affect graft success. Based on expert opinion and extensive clinical experience, the focus group agreed (94%) that supplemental fixation of an OCA is needed only if the graft is unstable, as might be the case in grafts that are not circumferentially contained and do not achieve a press fit. Despite the absence of evidence, there are several case series detailing the use of fixation to manage unstable grafts.[8,31,35] Additionally, unanimous consensus was established for addressing bony cysts beneath a lesion at the time of osteochondral allografting. While there is no specific clinical literature regarding management of cysts, all experts concurred that these should be addressed with curettage and bone grafting, preferably with autologous bone graft generated during host graft bed preparation. The discussions of surgical technique also led to the unanimous consensus of the ideal depth of a femoral OCA to measure between 6 and 10 mm. Wang et al[86] detailed the use of OCAs with a bone depth between 8 and 10 mm. A more recent article evaluating OCA bone depth concluded that 7 and 10 mm–length plugs had significantly better resistance to pullout and subsidence than the 4 mm–deep plugs.[4]

With regard to pulsatile lavage, several articles have evaluated the effectiveness of using pulse lavage on allografts to remove marrow elements and debris,[38,41,75] which is considered important to decreasing their potential immunogenicity and bioburden. Ibrahim et al[41] demonstrated that pulse lavage removed a significant amount of marrow content from morselized allograft bone—protein (70.5%), fat (95.2%), and DNA content (68.4%). A more recent study investigated the effect of lavage duration, flow intensity, and graft storage conditions on the extent of marrow removal from human osteochondral cores and showed increased marrow removal with greater lavage durations.[75] Besides reducing the immunogenicity of the graft, removal of marrow elements may also improve bone integration. A goat model showed increased bone ingrowth after rinsing allografts, suggesting that reduction of immunogenic factors in the marrow may improve bone incorporation.[81] With regard to biologic adjuncts enhancing bone incorporation of OCAs, the evidence is lacking and inconsistent. Two studies investigated the effects of autologous bone marrow

aspirate concentrate (BMAC) on bone integration.[61,85] In the first study, OCA augmented with BMAC did not enhance bone integration or affect cystic changes as compared with OCA without BMAC,[85] contradicting the findings of the second, which showed improved bone integration in the OCA group containing BMAC.[61] Various factors may influence outcomes, including methods to assess osseous integration, patient selection, graft matching, and BMAC harvesting technique and processing. The contradictory results in the literature support the need for additional research to understand the role and determine the effectiveness of biologic adjuncts in OCA.

Graft Matching

Level and Grade of Evidence. Of the 4 statements established for the graft-matching category (Table 5), 2 were supported by comparative clinical (level 3) and basic science (level 5) studies (grade C). The remaining 2 statements were expert opinion or supported by basic science studies (grade D).

Evidence Summary. There was strong consensus on defining the contralateral graft as an OCA from the opposite condyle and allowing its use for single-plug restoration. This has ramifications for optimizing donor tissue utilization, as the preponderance of lesions of the medial femoral condyle (MFC) in patients leads to a relative shortage of MFC grafts and a related surplus of lateral femoral condylar (LFC) grafts. The evidence supporting the use of a contralateral/nonorthotopic OCA for a single-dowel restoration has increased in recent years. Mologne et al[58] investigated OCA surface matching of LFC grafts into MFC 20-mm defects. The outcomes showed that MFC and LFC donors matched well, with an overall height deviation of 0.63 mm for area and 0.47 mm for stepoff, with no significant difference between them. These results are consistent with more recent studies demonstrating that a contralateral LFC graft can provide acceptable size and similar surface matching with MFC grafts.[80,88] These cadaveric studies were corroborated in a recent clinical study (level 3) comparing clinical outcomes of nonorthotopic or contralateral OCAs with traditional site-matched orthotopic OCAs.[80] Both patient groups significantly improved

TABLE 5
Level of Evidence and Grade of Evidence for Graft Matching[a]

| Statement | Level of Evidence (No. of Studies per Level) | | | | | | Grade of Evidence |
	1	2	3	4	5	Total	
A contralateral graft is an OCA from the opposite condyle (eg, a lateral condyle for a medial condylar procedure).[58,80]	0	0	0	0	2	2	D
A contralateral OCA can be utilized for single plug restoration up to 25 mm in diameter.[20,58,80,83,88]	0	0	1	0	4	5	C
Femoral condylar OCAs can be adequately size matched using condylar and/or tibial width measured on radiographs with magnification marker or MRI/CT.[20,82]	0	0	1	0	1	2	C
A standardized method for testing cartilage viability and metabolic activity should be established.	0	0	0	0	0	0	D

[a]CT, computed tomography; MRI, magnetic resonance imaging; OCA, osteochondral allograft.

clinically with no significant differences in failure rates and patient-reported outcomes, suggesting that condyle-specific matching is not necessary.

This growing body of literature evaluating contour, topography, and graft matching of OCAs in various cadaveric studies supports the width measurement of the femoral condyle or tibial plateau as the standard for size matching OCAs.[7,58,80,88] The experts strongly agree that femoral condyles can be adequately size matched using condylar and/or tibia width measured on radiographs with magnification correction or magnetic resonance imaging/computed tomography. A recent clinical study showed that graft-recipient anteroposterior mismatch was not associated with OCA failure or patient outcomes, suggesting that anteroposterior length mismatch is not an absolute contraindication for graft acceptance.[82]

With regard to cartilage viability, all experts concurred that a standardized method for testing cartilage viability and metabolic activity should be established. Chondrocyte viability is considered critical for durable osteochondral restoration, survivorship, and long-term outcomes. Pallante et al[63] investigated the effect of various OCA storage parameters on graft health using an in vivo goat model and demonstrated that reduced chondrocyte cellularity at the articular surface of OCAs at the time of implantation, as a result of various storage conditions, was associated with poor outcomes at 12 months. The importance of chondrocyte viability on successful osteochondral repair was supported in a canine in vivo model[73] demonstrating successful osteochondral repair with donor OCAs containing >70% chondrocyte viability and poor outcomes with grafts <70% viability. Gross et al[36] conducted a histological analysis of fresh OCA specimens retrieved at the time of revision surgery, which ranged from 1 to 25 years after the index OCA procedure, and demonstrated an association between viable chondrocytes and long-term graft survival. The histological analysis of early graft failures showed a lack of viable chondrocytes and cartilage and matrix staining,[36] consistent with the animal data.

Rehabilitation and Return to Sports

Level and Grade of Evidence. Out of the 3 statements established for the "rehabilitation and return to sports"

category (Table 6), 2 statements were supported by level 4 clinical studies (grade C), and 1 was based on expert opinion of the focus group (grade D).

Evidence Summary. Unanimous consensus was reached for all statements related to rehabilitation and return to sport. Various rehabilitation protocols and guidelines have been reported after OCA transplantation of the distal femur. The majority of studies before 2017 favored more restrictive postoperative weightbearing instructions, typically characterized as nonweightbearing initially for 6 to 8 weeks or a slow progression of toe-touch weightbearing (TTWB) during the initial convalescence.[‡‡] Studies published in 2017 and later generally reported more permissive postoperative weightbearing protocols in comparison with historic recommendations of strict nonweightbearing.[1,25,26,60,84] Nielsen et al[60] prescribed 4 to 6 weeks of TTWB, followed by a month of progressive weightbearing, and Frank et al[25,26] allowed immediate partial weightbearing with a hinged brace for 4 to 6 weeks. All subsequently reported significant improvement in patient-reported outcomes.[25,26] These recent studies aside however, a moderately restrictive weightbearing protocol after distal femur OCA transplants is most common and is supported by the results of this expert focus group.

With regard to rehabilitation protocols after patellar and trochlear reconstructions with OCAs, few studies exclusively focused on postoperative rehabilitation in the patellofemoral region. Although many reports included surgery in this anatomic area, at the patella,[10,14,55] trochlea,[12,19,45] or both,[1,25,26,60,84] few specified rehabilitation protocols in this subset. Cameron et al[12] reported on a cohort of trochlear allograft recipients who were permitted TTWB with a brace limiting knee flexion to <45° and progressive weightbearing by 8 to 10 weeks, depending on quadriceps function. They reported a graft survivorship of 78% at 5 years and 55.8% at 15 years, with significantly improved outcome scores. Although there are limited studies evaluating rehabilitation in the patellar and trochlear regions, the evidence is consistent with the established consensus statement. All

‡‡References 9, 10, 14, 19, 22, 27, 37, 45, 47, 49, 54, 55.

TABLE 6
Level of Evidence and Grade of Evidence for Rehabilitation and Return to Sports[a]

Statement	Level of Evidence (No. of Studies per Level)						Grade of evidence
	1	2	3	4	5	Total	
An initial period of partial weightbearing (up to 6 weeks) for tibiofemoral OCA reconstructions is appropriate.[b]	0	0	0	12	0	12	C
Weightbearing as tolerated in conjunction with extension bracing (up to 6 weeks) after patellar and/or trochlear OCA reconstructions is appropriate.[12,33]	0	0	0	2	0	2	C
Time (minimum 12 weeks from surgery) and functional recovery should both be used as criteria to return to impact activities.	0	0	0	0	0	0	D

[a]OCA, osteochondral allograft.
[b]References 2, 17, 19, 26, 31, 43, 45, 53, 54, 59, 60, 69.

respondents agreed that rehabilitation after OCA reconstruction of the patellofemoral region should include weightbearing as tolerated in conjunction with extension bracing (up to 6 weeks).

This consensus group agreed that time (minimum 12 weeks from surgery) and functional recovery should both be used as criteria to return to loading activities. Several studies addressed timing of return to impact activity and/or sport specifically. Universally, for sports, this is never before 3 months and more typically 4 to 6 months after an OCA transplant, generally with deference to functional capacity restoration.[§§]

DISCUSSION

The major outcome of this study was the development of consensus (>89% agreement) for 17 statements spanning surgical indications, graft matching, surgical technique, and rehabilitation/return to sport for OCA transplantation of the knee (Appendix). All but 1 statement in the indications category reached unanimous consensus. All experts agreed on appropriate indications, contraindications, and use of OCAs for primary and revision cartilage procedures. The evidence for this category was much greater than any other, which facilitated the high level of agreement. Numerous level 2, 3, and 4 studies spanning 2 decades supported the statements on patient indications. The statements in the surgical technique category were limited by lack of high-quality studies. Despite the paucity of evidence, most or all experts were in agreement on addressing unstable grafts and subchondral cysts intraoperatively. Most participants agreed that subchondral bone cysts underlying index chondral lesions should be selectively curetted during graft bed preparation, rather than coring the entire recipient socket to the depth of the cysts. While the use of pulsatile lavage was universally recommended, further work is necessary to evaluate the effects of marrow removal on immunogenicity and bony integration of OCAs,

as well as the optimal irrigant, volume, duration, pressure, and potential additives such as antibiotics. Given the limited and inconsistent literature evaluating the augmentation of OCAs with biologics,[61,85] the expert members all agreed that it is unknown if biologic adjuncts can enhance OCA bone incorporation and that this requires additional investigation.

Strong and unanimous consensus was established for all statements related to graft matching. All experts were in agreement on the utilization of contralateral grafts. A number of cadaveric studies and a level 3 clinical investigation corroborated this statement and validated empirical clinical practice. MOCA experts all agreed that chondrocyte viability corresponds to graft efficacy and outcomes and that a standardized method for testing viability and metabolic activity should be established, as currently there remains significant variability in assays and methodology. The category on rehabilitation and return to sports achieved unanimous consensus on all statements. Experts concurred on an initial period of protected weightbearing after OCA surgery, and most agreed that this could be advanced as tolerated for single well-contained dowel grafts. Grafts in the patellofemoral joint were unanimously felt to be amenable to weightbearing in extension, where the patella does not engage the trochlear groove. Of note, time and functional recovery were considered paramount over radiographic or other imaging parameters in determining return to impact loading.

The strengths of this study include the ability to leverage the MOCA Committee, consisting of leaders and experts in the field of OCAs, to develop the consensus statements. The use of the online surveys and methodology for executing the Delphi process allowed for blinded anonymous results of each round to provide transparency while avoiding any bias or bandwagon effect. The methodology also involved a systematic review of the literature to determine the quality of evidence for each statement. This analysis provided insights into areas lacking robust clinical data and opportunities for additional research to improve the quality of evidence and further the scientific understanding of OCAs. The in-person debate allowed for active exchange and the

[§§]References 10, 12, 19, 22, 25, 26, 47, 49, 84.

opportunity to discuss various viewpoints and the supporting evidence for those opinions.

While consensus statements provide a mechanism to address inconsistencies and controversies in the clinical community when evidence is lacking, there are limitations. A significant limitation of this study is the risk of nonresponse bias. Rounds 1 and 2 resulted in 100% and 91% response rates, respectively, and the final round resulted in a lower rate of 78%. Another potential source of bias was the method used to generate questions for the study. This process did not involve all members of the expert group and was not conducted anonymously. In this study, methods were implemented to avoid bias, including distributing all survey results, agreement percentages, consensus statements, and comments to the entire group anonymously after each round. While all the statements reached consensus and may be useful for understanding and guiding various aspects of OCA transplantation, it is not a conclusive standard that can address all aspects of treating chondral lesions. Recent, ongoing, and future studies continue to provide insights and evidence to support the use of OCAs for various indications and to drive improvements in surgical technique, graft matching, and rehabilitation protocols. The consensus statements will be updated when high-quality evidence is available to corroborate the statements, and further studies are needed to address additional areas of debate.

CONCLUSION

The main findings of this study led to the establishment of consensus statements to provide guidance on surgical management of chondral lesions with OCA transplantation. Unanimous agreement was established for statements describing indications and contraindications for OCA application, which were supported by clinical evidence. Despite limited evidence supporting management of cysts and unstable grafts, unanimous agreement was achieved. Consensus was established for further studies to understand and determine the efficacy of pulse lavage and biologic adjuncts for OCAs. The inconsistencies in the literature regarding assays and methodologies for testing chondrocyte viability led to the unanimous call for standardized methods for testing chondrocyte viability and metabolic activity. The consensus statements developed around graft matching were supported by recent cadaveric and clinical studies. Unanimous agreement was achieved for all statements describing rehabilitation and return to sports, despite the limited literature. Although strong and unanimous consensus was achieved in this study, many statements lacked directive-type evidence and highlight the need for high-quality clinical trials and data sharing, to substantiate these recommendations.

AUTHORS

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APPENDIX

Modified Delphi Process

An initial list of 14 questions was generated addressing (1) patient indications, (2) surgical technique, (3) graft matching, and (4) rehabilitation and return to sport. Members produced initial responses to the open-ended questions. The questions and responses were distributed anonymously to all participants through a blinded equally weighted electronic survey (Sli.do) initiating round 1 of the modified Delphi method. Participants used their knowledge of the literature and extensive clinical and scientific experience in the field to respond to the survey. The initial survey requested participants to "agree" or "disagree" with the responses for each question. The surveys included a comments section providing participants the opportunity to suggest modifications and additional items to the questions and responses. Results from the initial round of questions facilitated the development of a more structured questionnaire, which included blinded comments from the first round and was distributed to participants for the second round. Results from the second round were used to draft preliminary consensus statements, which were voted on and discussed in an in-person meeting of all participants at the Chicago Forum. The discussions and voting were based on a standardized format. Briefly, voting was conducted using electronic keypads. All votes were anonymous and weighted equally. Questions and statements were presented to the participants for discussion and opportunity to provide amendments. Each proposed amendment required additional participants to second and third the motion. If the amendment received 3 motions, a vote of agreement or disagreement was conducted, followed by an opportunity for rebuttal. The statements were amended if the total votes reached 66% in favor or a supermajority (two-thirds). This process was repeated for each proposed amendment, after which a final vote on the entirety of the statement was undertaken or until a motion was approved to table a statement. Following the final vote, the degree of agreement was based on the criterion levels of consensus, defined as follows: consensus, 66.6% to 79%; strong consensus, 80% to 99%; unanimous consensus, 100%. The level of agreement was measured for each proposed statement.

Systematic Literature Search Terms and Criteria

A general search was conducted using the following terms:

((osteochondral [All Fields] or osteoarticular [All Fields]) AND ("allografts"[MeSH Terms] OR 'allografts'[All Fields] OR 'allograft'[All Fields])) AND ("knee"[MeSH Terms] OR "knee"[All Fields] OR "knee joint"[MeSH Terms] OR ("knee"[All Fields] AND "joint"[All Fields]) OR "knee joint"[All Fields]).

Inclusion criteria, as summarized in Appendix Table A1, included studies reporting clinical data on fresh osteochondral allograft transplantation of the knee and basic science studies reporting outcomes related to cellular viability, graft matching, and in vivo evaluation of osteochondral allograft transplantation. Exclusion criteria involved transplantation of OCAs in defects of joints besides the knee, expert opinion articles, review articles, technique articles, studies with <5 patients, and osteochondral grafts that are synthetic, frozen allografts, or decellularized. The articles that met the inclusion criteria were screened to determine if they provided evidence related to (1) patient indications, (2) surgical technique, (3) graft matching, and (4) rehabilitation and return to sport. The references from the articles identified through these search criteria were analyzed to confirm completeness of the identified literature.

TABLE A1
Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Clinical studies (evidence levels 1-4) reporting outcomes of osteochondral allograft transplantation of the knee	Book chapters, conference proceedings, presentations
Basic science studies	Expert opinion articles
Systematic reviews	Review papers
Fresh osteochondral allografts	<5 patients
	Decellularized allografts, frozen allografts, or synthetic osteochondral grafts, bipolar

Centre for Evidence-Based Medicine Level of Evidence and Grades of Recommendation

The Centre for Evidence-Based Medicine's level of evidence (Appendix Table A2), which ranged from randomized controlled trials (level 1) to expert opinion and basic science studies (level 5), was used to evaluate the literature. The Centre for Evidence-Based Medicine's grades of recommendation were utilized to grade the identified literature for each statement.

Grade C represents level 4 studies or extrapolations from level 2 or 3 studies, where data are used in a situation that has potentially clinically important differences from the original study situation. Grade D describes level 5 evidence or inconsistent or inconclusive studies of any level.

TABLE A2
Levels of Evidence From the Centre of Evidence-Based Medicine[a]

Level	Type of Evidence
1A	Systematic review (with homogeneity) of RCTs
1B	Individual RCT (with narrow CIs)
1C	All-or-none study
2A	Systematic review (with homogeneity) of cohort studies
2B	Individual cohort study (including low-quality RCT)
2C	"Outcomes" research, ecological studies
3A	Systematic review (with homogeneity) of case-control studies
3B	Individual case-control study
4	Case series (and poor-quality cohort and case-control study)
5	Expert opinion without explicit critical appraisal or based on physiology bench research or "first principles"

[a]RCT, randomized controlled trial.