The Biomechanical Case for Labral Débridement

Ira Zaltz MD

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Abstract

Background Labral repair is increasingly performed in conjunction with open and arthroscopic surgical procedures used to treat patients with mechanically related hip pain. The current rationale for labral repair is based on restoring the suction-seal function and clinical reports suggesting improved clinical outcome scores when acetabular rim trimming is accompanied by labral repair. However, it is unclear whether available scientific evidence supports routine labral repair.

Questions/Purposes The questions raised in this review were: (1) does labral repair restore normal histologic structure, tissue permeability, hip hydrodynamics, load transfer, and in vivo kinematics; and (2) does labral repair favorably alter the natural course of femoroacetabular impingement (FAI) treatment or age-related degeneration of the acetabular labrum?

Methods An electronic literature search for the keywords acetabular labrum was performed. Three hundred fifty-five abstracts were reviewed and 52 selected for full-text review that described information concerning pertinent aspects of

labral formation, development, degeneration, biomechanics, and clinical results of labral repair or resection.

Results Several clinical studies support labral repair when performed in conjunction with acetabular rim trimming. Little data support or refute the use of routine labral repair for all patients with symptomatic labral damage associated with FAI. It is not known whether or how labral repair affects the natural course of FAI.

Conclusions Based on the current understanding of labral degenerative changes associated with mechanical hip abnormalities, the low biologic likelihood of restoring normal tissue characteristics, and mechanical data suggesting minimal consequence from small labral resections, routine labral repair over labral débridement is not supported.

Introduction

The structure and function of the acetabular labrum are of increasing clinical importance as the frequency of reconstructive procedures designed to improve hip function is performed. Open and arthroscopic techniques designed to reattach the acetabular labrum are intended to restore the recently described suction-seal function that permits interstitial joint fluid pressurization and evenly distributed fluid-film lubrication that prevents cartilage-to-cartilage contact. Routine repair of the labrum is largely based on higher clinical scores published in three reports published by Espinosa et al. [12] and Larson et al. [33, 34] that compared acetabular rim trimming with labral repair with rim trimming without labral repair in the management of pincer-type femoroacetabular impingement (FAI). Byrd and Jones [3], Santori and Villar [43], Farjo et al. [13], and Haviv and O'Donnell [20] have reported sustained

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I. Zaltz (✉)

Department of Orthopaedic Surgery, William Beaumont Hospital, 3535 W Thirteen Mile Road, Suite 744, Royal Oak, MI 48073, USA
e-mail: zaltzira@gmail.com

improvement in clinical scores after isolated labral débridement of various patterns of labral damage in patients without synovitis or arthritis. Recently reported *in vitro* biomechanical data by Greaves et al. [18] and Smith et al. [47] suggest there is a negligible deleterious effect on hip stability or cartilage consolidation after the removal or detachment of small amounts of the labrum.

The precise role of the acetabular labrum is not known with certainty and may differ between hips depending on multiple anatomic variables that include acetabular depth, acetabular orientation, and femoral anatomy. Furthermore, damage patterns to the acetabular labrum are known to differ depending on the underlying anatomy that is associated with the pathomechanics [2]. As such, there is little information on the *in vivo* effects of labral repair on joint mechanics, and, with the exception of studies published by Espinosa et al. [12], Larson et al. [33, 34], and Schilders et al. [44], there is limited clinical information to justify routine labral repair in all clinical settings that are associated with FAI.

This systematic literature review summarizes our understanding of embryonic and postnatal labral development, function, histology, biomechanics, and clinical studies related to labral repair and resection to determine whether the literature contains a scientific basis for the routine use of labral repair in the treatment of FAI. Specifically, (1) what information is published regarding development of the normal acetabular labrum; (2) is labral repair able to restore normal histologic structure, tissue permeability, hip hydrodynamics, load transfer, and *in vivo* kinematics; and (3) does labral repair favorably alter the natural course of FAI treatment or age-related labral degeneration?

Search Strategy and Criteria

A search of PubMed, OvidMedline, CINAHL, and the Cochrane Library was performed in July 2011 and repeated on April 20, 2012. The keywords acetabular labrum were searched and the results of the search were entered into Sente 6® (Third Street Software, Inc, Denver, CO, USA) to exclude duplicated citations. The initial search revealed 346 references and the subsequent search an additional 17 references. Non-English abstracts were excluded. Subsequently, each abstract was reviewed and nonapplicable citations were deleted. The exclusion criterion included abstracts associated with THA, Legg-Calve-Perthes disease, slipped capital femoral epiphysis, osteonecrosis, veterinary medicine, infant or childhood developmental dysplasia of the hip, acetabular components, infection, tumors, trauma, arthroscopic technique, review articles, and case reports. Fifty-six references remained and each

was reviewed. Studies were included if they were published in peer-reviewed journals and if they reported information on labral anatomy, histology, vascularity, innervation, biomechanics, and pathology. Relevant clinical studies with greater than 2 years of followup were included. Subsequently, a hand search of bibliographies of included studies was performed to obtain specific information that was published before 1950 that focused on embryology. Fifty-two references were included and reviewed for this study (Fig. 1).

Results

The entire human hip develops from a condensation of mesenchymal cells [49]. At approximately 23 mm (8 weeks), the anatomic elements of the mature hip, including the ligamentum teres, labrum, and capsule, are histologically identifiable [49]. In the fetal hip, the acetabular labrum is proportionally larger relative to the femoral head than in a mature hip. The peripheral location of the labrum in the mature hip is secondary to acetabular growth and elongation. The teleological importance of the labrum may relate to prenatal hip stability. Walker and Goldsmith [51] demonstrated that the acetabulum is relatively underdeveloped compared with the size of the femur and that the labrum covers a proportionally larger part of the femoral head during intrauterine development of the hip. Because the hip differentiates from a common mesoderm, it is understandable that developmental variations may involve the entire mass of differentiating tissue leading simultaneously to deformities of the acetabulum, labrum, and femur that are reflected in late gestational term and postnatal specimen that were published by Ponseti [41]. A recent histological study that used spontaneously aborted fetuses of varying gestational age focused on regional anatomic developmental differences within the acetabular labrum [4]. The anterior labrum and posterior labrum exhibit considerable anatomic and histological differences. Although the anterior labrum is characterized by a distinct transition, a marginal attachment, and a sulcus between the labrum and acetabulum, the posterior labrum forms a seamless transition and has a broader attachment [4]. There are regional histological differences that reflect ultrastructural variations within the labrum. Polarized microscopy suggests that collagen fiber orientation in the anterior part of the joint is parallel to the acetabular rim, whereas it is perpendicular in the posterior portion of the joint [4].

Postnatal acetabular and labral growth are well reported and based on MRI assessments. Horii et al. [23] reported a group of 40 Japanese children from three age groups and 10 adult control subjects who underwent radial sequence

Fig. 1 The flow chart describes the search strategy and selection criteria.

MRI to evaluate femoral coverage by the acetabulum and labrum. They noted the labrum covers proportionally more of the femoral head in children than in adults and there is progressive anterosuperior growth of the osseous acetabulum through adolescence when there is a relative decrease in size of the labrum.

Petersen et al. [40] described the adult acetabular labrum as a lamellar structure that surrounds the acetabulum and is attached anteriorly and posteriorly to the transverse acetabular ligament. It is composed of loose and dense connective tissue. They divided the labrum into three histological sections: articular side, central, and peripheral [40]. The articular side is composed of randomly oriented fibers. Deep to this area is a separate lamellar layer of dense collagen fibrils organized at various angles that corresponds to the fibrocartilage layer. This layer is thickest cranially and becomes smaller anteriorly and posteriorly. The external layer is the largest and composed of circularly oriented fibers that become continuous with the transverse acetabular ligament. Immunohistochemical studies suggest that the labrum is primarily composed of Type I collagen

with some Type II expression by the articular-sided chondrocytes. Staining for laminin found in the basement membrane of vascular endothelial cells suggests the articular side of the labrum is not vascularized [40].

The vascularity of the fetal labrum has been described in detail [38, 50]. When the acetabulum is arbitrarily divided into four quadrants and the capsular and articular portions are considered separately, the capsular side of the labrum is more vascular than the articular side and the number of blood vessels decreases throughout gestation. The regions with the greatest number of blood vessels are reportedly localized to the posterosuperior and anterosuperior quadrants [38]. A similar study demonstrated the vascular supply is entirely of capsular origin and that the articular-sided vessels penetrate through the labrum toward the joint. Moreover, the labral vascular anatomy is distinct from the acetabular supply [50]. This vascular organization appears to be preserved in adult hips with the capsular side of the labrum containing more blood vessels than the articular side [29]. The labrum is innervated on its external surface where multiple types of free nerve endings have been

localized to the loose connective tissue on the external surface. Nerve ending types include Vater-Pacini and Golgi corpuscles suggesting that the nerves serve both sensory and proprioceptive purposes [30].

In contrast to prior anatomic studies concerning the acetabular labrum that suggest resection of the labrum with or without resecting the transverse acetabular ligament does not substantially increase joint contact pressures [32], modern investigations by Ferguson et al. [14–16], Henak et al. [21], Greaves et al. [18], Smith et al. [47], and Song et al. [48] suggest the labrum is an important anatomic component necessary for normal hip homeostasis. Anatomically the labrum extends the articulating surface of the hip and increases the volume of the acetabulum [32]. Finite element load transmission studies suggest the labrum transmits minimal load in the nondysplastic hip [21]. In the dysplastic hip, however, the labrum transmits between 4% and 11% of the load across the hip [21].

Ferguson et al. [14] published a finite element study suggesting the labrum has the potential to act like a seal enabling pressurization of fluid within the joint, thus preventing physical cartilage contact and decreasing stress within the articular surface. This model assumed that the hip is spherical, that the cartilage acted in a poroelastic fashion so as to account for tissue with both solid and fluid properties, and that the labrum was sufficiently stiff to withstand pressurization. Material property studies using bovine labra suggest it is stiffer in tension than articular cartilage and that it has low permeability comparable to meniscal cartilages, providing circumstantial evidence for the finite element pressurization model [16]. Further investigation that was designed to measure both intra-articular pressure and cartilage creep during static and cyclic joint loading supports the finite element analysis [15]. These in vitro data suggest intraarticular pressure varies proportionately with labral integrity and cartilage consolidation is more rapid after labral disruption, thus supporting the previously mentioned finite element studies proposing a suction-seal mechanism [15]. Theoretical calculations that assume a complete labral seal, normal articular cartilage, and normal synovial fluid thixotropy confirm homogeneous pressurization of synovial fluid that maintains separation of articular surfaces. Inflammatory synovial fluid, degenerative articular cartilage, and disruption of the labral ring lead to nonhomogeneous fluid pressurization and increased contact between articular surfaces [22].

Ishiko et al. [24] mechanically tested labra harvested at the time of THA on dysplastic joints and found male labra are stronger than female and that osteoarthritic joints had the weakest labra, most likely secondary to degeneration. Crawford et al. [9] investigated the relationship between axial loading in external rotation and found that capsular venting and 15-mm labral tears were found to increase the

degree of external rotation and displacement under tested loads and to increase the instability of the joint. Investigating strains that develop within the anterior acetabular labrum during external rotational and abduction moments that were designed to simulate athletic hip load, Dy et al. [11] demonstrated that such maneuvers produce considerable strains within the anterior acetabular labrum and may represent another pathomechanical pathway to labral degeneration. The material properties of nonarthritic labral tissue were evaluated by Smith et al. [46]. They found the tensile and compressive modulus was substantially lower in the labrum from the anterior quadrant of the acetabulum compared with other parts of the joint. Safran et al. [42] measured circumferential strains across the acetabular labrum in cadaveric hips subjected to a variety of passive movements. When the labrum was divided into four quadrants, they found the strains are greatest in the posterior labrum, especially in flexion with or without adduction. Strains increase in the anterior labrum in flexion and increase in the lateral labrum in abduction.

Greaves et al. [18] attempted to quantify the effects of a torn, repaired, and resected acetabular labrum on cartilage strain using a 7-T MRI. A 3-cm labral detachment did not change cartilage strain, whereas labral repair decreased the strain by 2%, and labral resection increased the maximum strain by 6%. Smith et al. [47] reported on the effects of different sized acetabular labral tears on hip stability and labral strain. Radial tears and labral detachment tears up to 3 cm did not substantially decrease joint stability. Labral resection greater than 2 cm increased instability in subphysiological compression. Recently, Song et al. [48] demonstrated that focal labrectomy increases the resistance to rotation when nonarthritic hip specimens are subject to cyclic loading at 0.5, one, two, and three times body weight, supporting the theory that pressurization of joint fluid decreases joint friction. These studies present limited information on the morphology of the acetabula included in the experiments.

Cegini et al. [6] investigated the pathomechanics of various combinations of acetabular depth and femoral head-neck morphology using finite element analysis. Stresses within the joint were lowest for normal joints with a center-edge angle between 20° and 30° and an α angle less than 50°. In contrast, dysplastic acetabuli exhibit rim overload in the stance phase and combinations of increased acetabular depth or α angle lead to increased forces associated with large motions [6].

Anatomic skeletal morphology that causes FAI and hip instability generates pathologic shear and compression forces primarily at the acetabular rim [6, 10, 17, 31]. Recent studies suggest activity-specific movements are capable of causing pathologic forces that may be responsible for cartilage damage [5]. Chondral lesions affecting either the

labrum or the acetabular hyaline cartilage have been reported [2, 26, 27, 37]. The histological findings associated with degeneration of the acetabular labrum include cystic degeneration within the acetabular labrum, microvascular invasion into the damaged labrum, increased chondrocyte and fibroblast proliferation, and intralabral ossification [25, 45]. The data from Ito and Seldes suggest the pathologic findings are probably the same whether degeneration occurs prematurely with associated pathologic skeletal anatomy or as a result of age-related hip use.

There is strong observational evidence suggesting labral and adjacent cartilage degeneration occurs as a natural course of aging [36]. Multiple MRI studies have demonstrated that degenerative signal within the acetabular labrum is prevalent. Lecouvet et al. [35] reported on 200 asymptomatic subjects with a mean age of 44 years and noted that the homogeneous triangular shape of the labrum is more prevalent in younger subjects and that intralabral signal abnormality communicating with the articular side of the labrum is encountered more frequently in older subjects. These findings were independently confirmed by Cotten et al. [8]. Aydingöz and Öztürk [1] studied 180 volunteers and noted progressive loss of triangular shape and homogeneous intralabral signal with age. In addition, 15% of the subjects had asymmetric labral size and 25% had asymmetric labral shapes. These studies confirm normal age-related changes within the acetabular labrum. They only differ in that Lecouvet et al. report absent labrum as the second most common variant, whereas Aydingöz and Öztürk report absent labrum as the least common variant.

Acceptance of the current theory on the pathogenesis of hip arthritis assumes most hips deteriorate as a result of pathologic mechanics related to variations in skeletal morphology that lead to either instability or impingement [7]. Related to this theory is the presumption that normal mechanics are dependent on labral function where the intact acetabular labrum is important in maintaining stability, regulation of synovial fluid flow, and proprioception [14, 30, 45]. The association between labral damage and skeletal dysmorphism has been shown by Guevara et al. [19] and Wenger et al. [52]. That labral disruption contributes to hip pain is certainly possible given the presence of nociceptors within the labrum and that labral degeneration is associated with inflammation.

Clinical experience suggests selective labral débridement can produce improvement in hip symptoms. Byrd and Jones [3], Santori and Villar [43], and Farjo et al. [13] published different clinical scores after selective labral débridement. The studies are in agreement that a favorable outcome is more likely in the absence of substantial hip arthritis. Approximately 70% of nonarthritic hips maintain clinical improvement at 3- to 10-year followup. None of the publications provides data regarding the anatomic

characteristics of the hip, although Farjo et al. included patients believed to have dysplasia in their analysis. Because the average age in each series was older than 40 years, it is likely the majority of patients probably had a component of FAI or age-related labral damage. More recently, Haviv and O'Donnell [20] reported 81 patients with a mean age of 44 years who had painful hips associated with labral tears and no bony dysmorphism. In the absence of major synovitis or arthritis, they reported clinically substantial improvement measured using the modified Harris hip score after labral débridement.

In contrast, three studies [12, 33, 34] suggest when labral reattachment is compared with labral resection in the open and arthroscopic treatment of pincer-type FAI, repair leads to improved clinic outcomes. Espinosa et al. [12] reported that patients who underwent acetabular rim trimming with labral refixation had improved clinical Merle D'Aubigné scores at 1 and 2 years when compared with the resection group. Similarly, Larson and Givens [33, 34] reported that patients with pincer-type impingement had improved modified Harris hip scores, SF-12, and visual analog scale scores when acetabular rim trimming was combined with labral refixation performed arthroscopically. A recent publication comparing labral débridement with labral repair in all patients treated arthroscopically for FAI suggest modestly better modified Harris hip scores in the repair group. However, labral flap tears were more prevalent in the resection débridement group, whereas labral detachment was more prevalent in the repair group suggesting different underlying pathomechanics [44].

There exist anecdotal evidence that labral débridement in the setting of structural instability has an unpredictable course [39]. Although successful treatment for acetabular dysplasia is still possible after failed arthroscopy [28], a precise indication for suitable candidacy for labral débridement in dysplastic acetabula does not exist.

Discussion

The structure and function of the acetabular labrum are of increasing clinical importance as the frequency of reconstructive procedures designed to improve hip function is performed. This review summarizes the development, growth, function, and biomechanical properties of the acetabular labrum. It examines information that is needed to answer two specific questions: (1) does labral repair restore normal histologic structure, tissue permeability, hip hydrodynamics, load transfer, and in vivo kinematics; and (2) does labral repair favorably alter the natural course of FAI treatment or age-related labral degeneration?

Readers should be aware of the key limitations in the literature and in this review in particular. First, the clinical

data that have been presented are Level III and IV data that do not accurately categorize the labral damage nor precisely describe the morphology of the acetabulum or femur. Second, no prospective study exists that compares treatment modalities with each other or with the untreated natural history of the symptomatic hip. Third, the finite element studies that form the basis for the suction-seal function of the labrum are based on certain assumptions. These include a perfectly spherical hip, normal articular cartilage, consistent synovial fluid composition, and functioning labral tissue. These models do not account for the wide variation in femoral and acetabular anatomy, articular cartilage integrity, or labral quality that is treated clinically. As such, the precise role and relative importance of the suction-seal is not known with certainty. Fourth, it is not known how currently used labral repair techniques that include looped and translabral sutures of differing caliber affect the material property of already damaged labrum. Fifth, in vitro mechanical studies are performed with a variety of normal specimens of varying ages. These specimens differ substantially from morphologically abnormal hips that are seen in clinical practice. Furthermore, the experimentally induced damage is not similar to clinically described damage patterns.

The level of basic scientific evidence to either support or discourage routine repair of the acetabular labrum is low [12, 33, 34]. There are no in vivo or in vitro studies that demonstrate repair of the acetabular labrum is capable of restoring normal histologic structure, tissue permeability characteristics, and fluid flow hydrodynamics within the hip. There are multiple theoretical models [14, 15] and in vitro studies that investigate the effect of labral resection or detachment on joint stability [32, 47], cartilage consolidation [18], resistance to rotation [48], and load transfer [6] that demonstrate alterations in hip mechanics after varying types of experimental labral alteration. There is no basic evidence that proves repairing the experimentally induced damage reverses the experimentally observed changes in the mechanical properties of the hip.

The level of evidence to support routine labral reattachment is low. There is growing evidence to support labral reattachment in conjunction with an acetabular rim osteoplasty [12, 33, 34]. The level of evidence to support routine repair of all labral damage associated with FAI is low and improvement in various outcome scores is reported after both repair and débridement. There is no information to support that labral repair either beneficially or detrimentally alters the natural history of FAI.

Based on the known skeletal contributions to degeneration of the acetabular labrum, and clinical outcome scores that support improvement after both labral débridement and labral reattachment, the current data do not support routine labral repair nor do they support routine labral débridement

in all circumstances. The existing in vitro mechanical data suggest labral débridement is appropriate in certain clinical circumstances for the following reasons. First, described pathologic findings in degenerative labra likely have substantial structural and functional consequences that alter normal labral tissue function. Because the circumferentially oriented collagen fibers are degraded and the permeability of the labral tissue is probably altered, it is not likely that simply reattaching the labrum restores normal tissue characteristics. Moreover, little data exist to document the effect of varying labral repair techniques, suture types, or exposed intraarticular suture on the function of the labrum. Second, studies suggesting labral repair leads to improved clinical results were performed on patients who underwent acetabular rim trimming and should not be extrapolated to all patients with labral pathology. Inferior clinical results obtained after labral resection in the setting of rim resection are intuitively akin to the previously discussed biomechanical studies that demonstrate increased cartilage consolidation and instability after resections greater than 2 to 3 cm [18, 47]. Based on these studies, limited labral débridement is not likely to affect stability, cartilage consolidation, or resistance to rotation. Furthermore, proper correction of the skeletal pathomorphology that is the mechanical basis of labral degeneration may be more important clinically than labral reattachment.

In conclusion, localized débridement of degenerative labral tissue should be considered if there is no need for surgical modification of the acetabular rim, when there is no suspicion of instability of the hip, and when the labral débridement leaves a rim of healthy labral tissue. Further clinical and basic studies are necessary to define the role of the acetabular labrum in hips that are clinically affected by FAI. Prospective studies are needed to compare labral débridement and labral repair and to determine if there is an alteration of the natural history in hips affected by FAI. Basic studies are required to define the function of the labrum in morphologically abnormal, symptomatic hips and to determine the mechanical properties of the healed labrum. Last, the mechanical effect of varying repair techniques needs further clarification.

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