Damage to and repair of the acetabular labral-chondral complex are areas of clinical interest in the treatment of young adults with pain in the hip and in the prevention of degenerative arthritis of the hip. There are varying theories as to why most acetabular tears are located anterosuperiorty. We have studied the prenatal development of the human acetabular labral-chondral complex in 11 fetal hips, aged from eight weeks of gestation to term.

There were consistent differences between the anterior and posterior acetabular labral-chondral complex throughout all ages of gestation. The anterior labrum had a somewhat marginal attachment to the acetabular cartilage with an intra-articular projection. The posterior labrum was attached and continuous with the acetabular cartilage. Anteriorly, the labral-chondral transition zone was sharp and abrupt, but posteriorly it was gradual and interdigitated. The collagen fibres of the anterior labrum were arranged parallel to the labral-chondral junction, but at the posterior labrum they were aligned perpendicular to the junction.

We believe that in the anterior labrum the marginal attachment and the orientation of the collagen fibres parallel to the labral-chondral junction may render it more prone to damage than the posterior labrum in which the collagen fibres are anchored in the acetabular cartilage. The anterior intra-articular projection of the labrum should not be considered to be a pathological feature.

Tears of the acetabular labrum have been recognised as a common cause of pain in the hip in young adults.1-3 Neumann et al4 recently noted that 66% of patients presenting with mechanical symptoms in their hip were found to have labral tears seen on MR arthrography, with most being located anteriorly. More importantly, as described by McCarthy et al,5 most tears of the anterior labrum are associated with degenerative changes in the articular cartilage. It is still unclear whether a labral tear or chondral injury is the initial insult which results in degenerative joint disease.6,7 A high association of these lesions with bony dysmorphicisms of the hip has been reported,8,9 leading some authors to suggest that there is a causal relationship between these two phenomena.6,10 Others have proposed that disruption of the acetabular labral-chondral complex may be because of its underlying anatomical features.5

Although the body of literature describing labral pathology is growing,11,12 there are relatively few studies of the anatomy of the fetal labrum and its chondral junction. Our aim was to analyse the embryology of the acetabular labral-chondral complex in order to provide a better understanding of the aetiology of these disruptions, and to clarify some of the controversies regarding the normal anatomy of the acetabular labrum.

Materials and Methods
Our study was based on the embryo collection of The Bone and Joint Research Laboratory of the University of Ottawa. All the fetuses had spontaneously aborted. They were inspected and weighed by members of the pathology department and preserved in 10% neutral formalin for at least three months. The provincial laws of Ontario forbid conducting scientific studies before this time. The hips were then removed in toto, decalcified in ethylene diamine tetra-acetic acid, serially sectioned in the frontal, transverse and sagittal planes, mounted on glass slides and stained with haematoxylin and eosin and azan. The first author (MC) went through the collection and identified 11 specimens cut exactly in the sagittal plane, which is the only plane in which both the anterior and posterior labra can be seen. The age of the specimens ranged between eight weeks of gestation and term.
To clarify further the orientation of the hips it must be remembered that the coxofemoral joint of the human fetus is held in a position of at least 90° of flexion, thereby influencing the relationship between the acetabulum and the femoral head, with the inferior part of the head in contact with the anterior portion of the acetabulum. The formation of one cartilage anlage for each hemipelvis is another important embryonic feature. Microscopic evidence of centres of ossification for the ilium, pubis and ischium become visible at the beginning of the fetal period (eight weeks). The position of flexion of the hip brings the anterior part of the head into contact with the superior part of the acetabulum. When in an erect position, subjects would show a possible offset of the femoral head in the sagittal plane, but this is only shown in the frontal plane during the intra-uterine period. Consequently, it could not be appreciated in the sagittal sections used in our study.

The specimens were examined by both light and polarised light microscopy. The anterior and posterior acetabular labral-chondral complexes were carefully compared. Microscopic analysis included the morphology of the complex, histological examination of the labral-chondral transition zone and the orientation of the collagen fibres.

Results
There were considerable morphohistological differences between the anterior and posterior labral chondral complexes which were consistent throughout all ages of gestation.

Morphologically, there was a striking difference between the two anatomical regions of the acetabular labrum (Fig. 1). The anterior acetabular labral-chondral complex had a somewhat marginal attachment to the acetabular cartilage and seemed to cap its anterior part. There was an intra-articular labral projection which formed a recess between the articular surface of the acetabulum and the labrum. The posterior labrum differed in that it was directly attached to and continuous with the acetabular cartilage. It lacked a labral projection into the articular space.

Under higher magnification, two further differences between the anterior and posterior labral chondral complexes were observed. The first involved the transition zone from the acetabulum to the labrum, i.e., the attachment site of the labrum to the acetabulum. Anteriorly, there was a sharp, abrupt transition at the junction of the cartilaginous acetabulum and the labrum. By contrast, posteriorly, the transition was gradual and interdigitated (Figs 2 and 3).

The second histological difference was found in the orientation of collagen fibres at the junction of the acetabular cartilage when examined under polarised light. Anteriorly, the collagen fibres ran parallel to the labral-cartilage junction, but posteriorly they were perpendicular to this junction (Figs 4 and 5).

Discussion
It is only recently that surgeons have been able to identify labral pathology in a reproducible manner, both from a radiological and surgical standpoint. There have been few descriptions of the anatomy of the labrum and its attachment. The first detailed analysis was that of Seldes et al. in which cadaver and embalmed specimens were studied. They found that over 95% of the cases had evidence of labral tears, which were subdivided into two types. Most were located in the anterosuperior quadrant. Type I was defined as a detachment of the labrum from the surface of the articular cartilage and type II as fraying or tearing of the labral substance. They concluded that acetabular tears were a common finding in the ageing hip. These results were consistent with those reported by Byers, Contepomi and Farkas in which 88% of the hips examined at post-mortem had a tear at the labral-chondral junction. Both of these studies were carried out on adults and based on these findings, it was assumed that a lack of continuity between the anterior labrum and the acetabular cartilage was a pathological feature. However, few studies have investigated the embryological development of the labrum and the acetabular articular cartilage. The intra-articular projection of the former, which we describe, may be a normal variant. Therefore, our findings contradict the belief...
that a disconnection between the anterosuperior labrum and articular cartilage is a pathological finding. This is in contrast with the uniform transition zone of the posterior acetabular labral-chondral complex.

Our findings are of clinical interest since the association between labral and chondral damage, as well as the aetiology of labral tears, is still being debated.\textsuperscript{6,9,17,18} It is likely that there is a spectrum of abnormality, which culminates in
Degenerative joint disease. A causal relationship between labral and chondral pathology has yet, however, to be established, and the pathogenesis of labral tears still remains unclear.

A preponderance of tears at the anterior labral-chondral junction has been described, based on both arthroscopic\textsuperscript{11,18} and cadaver studies.\textsuperscript{11,16,18} McCarthy et al\textsuperscript{15} concluded that the acetabular labral-chondral complex was a site at risk and called it the “watershed lesion”. They postulated several explanations for this anatomical predilection. These included potentially inferior mechanical properties, higher mechanical demands and a relative hypovascularity of the anterior acetabular labral-chondral complex. Based upon further work, they proposed that a labral tear may alter the biomechanical environment of the hip leading to degeneration of the articular cartilage and eventual osteoarthritis.\textsuperscript{7}

More recently, labral and chondral damage has been associated with femoroacetabular impingement,\textsuperscript{6} a known cause of idiopathic osteoarthritis of the hip.\textsuperscript{10} Ganz et al\textsuperscript{10} described it as a bony dysmorphism of the hip which caused abnormal contact between the anterior rim of the acetabulum and the proximal femur, leading to damage to the articular cartilage. There are two types of femoroacetabular impingement. Cam impingement occurs in an outside-in mechanism in the presence of decreased femoral head/neck offset, while pincer impingement is the result of an abnormality of the acetabulum. Therefore, in contrast to the watershed theory, Ganz et al\textsuperscript{10} concluded that labral and chondral damage occurred in the presence of structural bony abnormalities of the hip rather than as an intrinsic abnormality of the acetabular labral-chondral complex, and that acetabular chondral damage is the initial insult leading to tearing of the labrum.\textsuperscript{5}

Although the debate will continue as to the exact pathomechanism leading to labral-chondral damage, as well as arthritis, our study provides new information as to the differences between the anterior and posterior acetabular labral-chondral complexes during fetal development. Previous studies\textsuperscript{11,16} on the disruption and degeneration of the anterior acetabular labral-chondral complex have been carried out on adult cadavers with evidence of arthritic changes. This made it difficult to establish a causal relationship between disruption of the anterior acetabular labral-chondral complex and the development of arthritis of the hip. In all of the specimens which we examined, there was a consistent histological difference between the anterior and posterior fetal acetabular labral-chondral complex. The anterior aspect had a more peripheral attachment to the acetabular cartilage and a sharper, more abrupt transition zone, compared with the posterior. This combined with its intra-articular projection, may make the anterior labrum more prone to tearing, since it may be less likely to withstand shearing forces compared with the seemingly firmly-attached posterior labrum. This theory is further
substantiated by the orientation of the collagen fibres at the posterior acetabular labral-chondral complex which are perpendicular to the labral-chondral junction anchoring the labrum to the acetabular cartilage. In the anterior acetabular labral-chondral complex their orientation is parallel to the junction. We recognise that to validate our findings further, we need to have numerous specimens at each stage or week of gestation in order to determine whether the findings are consistent throughout a population of fetuses of similar maturity.

A histological study of the fetal acetabular labrum in 1981 \(^{19}\) first reported the presence of defects at the anterosuperior margin of the labrum in seven of 74 specimens. They were only detectable under light microscopy and, therefore, were thought to be potentially attributable to fixation artefact. A similar anatomical variation of the acetabular labrum was reported in arthroscopic and radiological studies. \(^{1,20-23}\) This variation was first described by Byrd\(^1\) as a “partial separation of the labrum from the lateral aspect of the bony acetabulum”, and was in the anterosuperior portion. Byrd\(^20\) subsequently noted that these “normal anomalous variations” were common, although he did not state the specific location in which they could be found. Some have also described, at the time of arthroscopy, a sublabral groove at the posteroinferior edge of the acetabulum. \(^{21}\) In a more extensive study, Saddik et al\(^23\) noted, again at the time of arthroscopy, that 27 of 121 patients (22%) were found to have sublabral sulci (two patients had more than one) which were located anterosuperiorly in 12 (10%), posteroinferiorly in 14 (12%), anteroinferiorly in two (2%) and posterosuperiorly in two (2%). In this retrospective analysis,\(^23\) these sulci could be detected with an accuracy of 70% on MRI. In a smaller study, Dinauer et al\(^22\) described a normal posteroinferior sulcus or groove in four of 23 hips (17.4%), all of which were detected on MR arthrography, and an anterior cleft at the junction of the anterior labrum and transverse ligament in 19 of 58 hips (32.8%). In both of these studies, a sublabral sulcus was defined as a cleft between the labrum and the adjacent articular (hyaline) cartilage, which had smooth, non-frayed, non-healing edges.

These studies provide evidence that non-traumatic detachment of the labrum exists in a considerable proportion of subjects. However, they have some limitations since the MR arthograms were reviewed retrospectively to determine the prevalence and location of these sulci,\(^{22,23}\) the exact location of which can be difficult to interpret. They were undertaken in abnormal hips, with some form of intra-articular pathology, making it difficult to classify them as completely benign. Nevertheless, these \emph{in vivo} studies do confirm the presence of non-traumatic labral-chondral clefts or sulci and our study provides new information as to the presence of these structures in the normal population.

Our findings need to be taken into consideration when examining the acetabular labral-chondral complex at the
time of surgery. A diagnosis of disruption of the anterior complex based on a comparison with the posterior complex may be erroneous. Indeed, a so-called type-I tear, defined as a detachment of the labrum from the articular surface without associated fraying or injury to adjacent articular cartilage, may actually represent normal anatomy, or even a remnant of the embryological intra-articular projection observed in our study. This may also have implications for the current indications for repair of labral tears, since a free intra-articular projection which is damaged may not require detachment and refixation of the labrum but simply a limited debridement.

Our study has some inherent limitations in that the vascularity of the labral-chondral junction could not be evaluated because of the way in which the specimens have been prepared. Previously, Kelly et al were able to demonstrate that in human cadavers the labrum was well vascularised on its capsular side and more so at the bony attachment. Another limitation was that we could not account for possible changes in the appearance of the labrum as the child assumes an erect posture. A study of asymptomatic individuals by MRI and MR arthrography may help to delineate further the true anatomy of the acetabular labral-chondral complex. This may indicate whether a flap-like anterior labrum is present even in the absence of known pathology of the hip. Furthermore, we examined a relatively small number of specimens but despite this, the consistency of the pre-natal features of the acetabular labral-chondral complex across all fetal age groups further validates our findings that there are differences between the anterior and posterior complexes which may make the anterior labrum inherently more susceptible to tear compared with the posterior. Recent arthroscopic findings support the fact that these differences appear to persist into adulthood. As the use of hip arthroscopy to diagnose and treat acetabular labral pathology associated with femoroacetabular impingement becomes more common, it is important that the normal anatomy of this region is well understood so that surgeons may correctly interpret their intra-operative findings.

Supplementary Material
A further opinion by Mr R. N. Villar and Mr J. Bunn is available with the electronic version of this article on our website at wwwjbjs.org.uk

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References