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Notchplasty in anterior cruciate ligament reconstruction: A systematic review of clinical outcomes☆

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ABSTRACT

Introduction: Notchplasty is an adjuvant procedure performed during Anterior Cruciate Ligament reconstruction (ACLR) with the purpose of widening the intercondylar notch of the femur. Its use is controversial due to its biomechanical influence on the knee and the potential for increased complications. The purpose of this systematic review is to evaluate the outcomes of patients who underwent ACLR with notchplasty.

Materials and methods: A systematic search of Cochrane, Embase, and Medline was conducted to identify papers evaluating clinical outcomes of patients who underwent ACLR with notchplasty. Inclusion criteria encompassed human studies with a control group, reporting clinical outcomes such as graft failure, graft rupture, range of motion values, and patient-reported outcomes.

Results: A total of 4 studies were included comprising 396 patients (129 with notchplasty, 235 without). No significant differences were reported regarding graft survivability or Lysholm score between those with notchplasty and those without. One study reported significantly reduced rates of revision surgery after ACLR with notchplasty. There were conflicting complication rates between studies regarding chronic synovitis and arthrofibrosis.

Conclusion: Patients who undergo notchplasty during primary ACLR have similar outcome scores and risk of graft failure compared to those who do not undergo notchplasty. Notchplasty patients may also be at a higher risk for loss of extension and chronic synovitis.

1. Introduction

Anterior cruciate ligament (ACL) injury is a common orthopaedic injury, with an estimated annual incidence of 1 in 3000 in the United States.[1] As such, ACL reconstruction (ACLR) is among the most common orthopaedic procedures, with over 100,000 performed annually.[2] Techniques of ACLR vary widely regarding surgical approaches and adjuvant procedures.[3–7] One of these procedures is notchplasty, however, its utilization in the setting of primary ACLR is debatable with many surgeons shifting towards an anatomic ACLR technique.[8]

A narrow intercondylar notch is associated with increased primary ACL injury rates, graft degeneration, and rupture in various populations.[9–14] Notchplasty is an adjuvant procedure performed during ACLR that involves bone and cartilage excision from the intercondylar notch of the femur.[15] The purpose of notchplasty is to widen the intercondylar space to avoid lateral wall and superior notch impingement of the ACL graft during terminal extension and to improve visualization during arthroscopy.[16] However, there are concerns that notchplasty alters knee biomechanics, increases intra- and postoperative blood loss, leads to increased risk of arthrofibrosis, and decreases post-operative healing.[8,17–19] There is a current paucity of literature that explores the relationship between ACLR failure and clinical outcomes with or without notchplasty.

This systematic review aims to compile outcomes after ACLR in patients who undergo notchplasty compared with those who do not. We hypothesize that patients undergoing notchplasty experience similar patient-reported outcome measures (PROMs), ACLR survivability, complications, and range of motion findings when compared to patients who do not undergo notchplasty.

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2. Methods

This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting systematic reviews.

2.1. Search strategy

Prior to beginning the literature search, a search protocol was created and published online in the PROSPERO International Prospective Register of Systematic Reviews (CRD42024586664) database. A search strategy was then implemented to query the databases of Cochrane, Embase, and Medline with no restriction on publication date. The initial literature search was conducted on July 10, 2024. This search strategy aimed to identify all studies that investigated the use of notchplasty during ACLR. Search terms were designed to capture relevant articles. Examples of terms are "notchplasty", "roofplasty", "Anterior Cruciate Ligament Reconstruction", "impingement", and "graft failure". Inclusion criteria were: (i) human subjects, (ii) primary studies that assessed the use of notchplasty during ACLR (iii) included clinical outcomes such as graft re-tear and failure rates, patient-reported outcomes, complications, and range of motion values, (iv) possessed a group of patients who underwent notchplasty and a control group, and (v) published in English. Exclusion criteria were: (i) notchplasty being performed in a procedure other than ACLR (i.e. to treat mucoid degeneration or partial ACL tears), (ii) lack of an internal control group, and (iii) lack of clinical outcomes as stated above.

2.2. Assessment of eligibility and study selection

The initial database search yielded 361 papers. After removing 59 duplicate studies, 302 studies remained. Two independent reviewers (C. R. & A.M.) applied the aforementioned exclusion criteria to the titles and abstracts of the studies, resulting in 238 studies being removed. Following this, a full-text review of the remaining 64 articles was conducted by A.M. and C.R. based on the established inclusion criteria. Any disagreements encountered during this process were resolved by a third reviewer, M.H. Following the search process, 4 papers were identified that fit the criteria for the systematic review. A PRISMA flow chart detailing the search strategy is included in Fig. 1.

2.3. Assessment of study quality

Study quality was assessed using the Critical Appraisal Skills Programme (CASP) checklist. Scores of the included studies ranged from 8 to 11, with an average score of 9.4 indicating good quality.

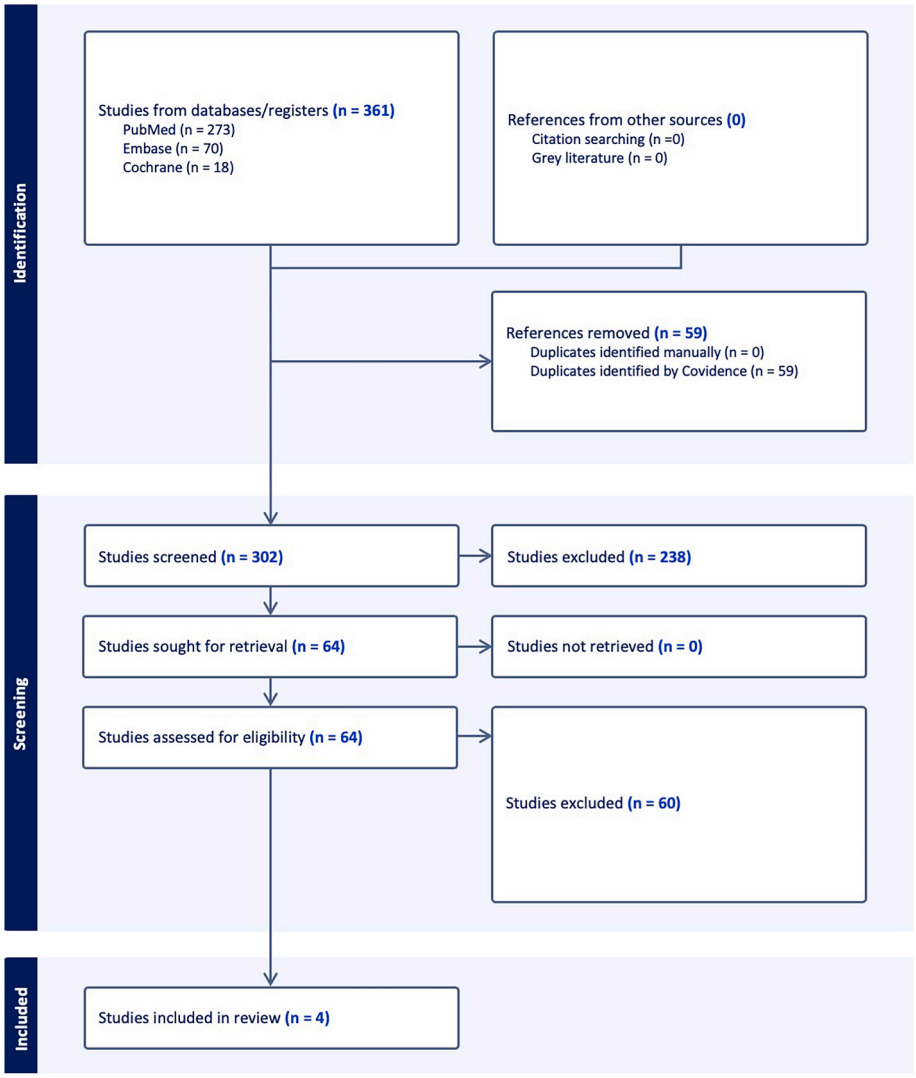

Fig. 1. PRISMA Flowchart of study selection.

2.4. Data extraction

Data extraction of the included studies was conducted by three reviewers. Extracted data included: (1) study characteristics: title, author, publication year, study design; (2) study population: number of patients, gender, average age; (3) number of patients that underwent notchplasty and those who did not; (4) follow-up interval; and (5) clinical outcomes of patients that underwent notchplasty.

2.5. Data analysis

Following data extraction, pooled data analysis was performed using Microsoft Excel, Office 365 Subscription, Version 16.86 (24060916) to calculate basic statistics such as weighted means and standard deviations for population characteristics. Due to the heterogeneity of included studies, statistical comparative analysis of outcomes was not possible.

3. Results

3.1. Study characteristics

Descriptive characteristics of the included studies are found in Table 1. A retrospective study design was the most common,[20,21] with Pape et al.[19] and Koga et al.[22] employing a prospective cohort design. Dates of publication ranged from 1995 to 2022. The total number of patients across studies was 396, with 129 patients undergoing notchplasty during ACLR and 235 who did not. The weighted average follow-up was 26.6 ± 7.8 months across studies, ranging from 12 to 36 months.

3.2. Patient characteristics

Full demographic data is found in Table 2. Of the 396 patients, there were 231 (58 %) males and 165 (42 %) females. The weighted average age of patients was 23.9 ± 1.9 years. Four different types of ACL grafts were used across studies. Hamstring autografts were used in 313 patients (79 %), bone-patellar tendon-bone (BTB) autografts in 61 patients (15 %), quad tendon autografts in 19 patients (5 %), and allografts in 3 patients (1 %).

3.3. Outcomes

A full list of outcomes is organized in Table 3.

3.4. Graft tear

Koga et al.[22] reported no difference in graft rupture rate at a 2-year follow-up. Thompson et al.[21] found that notchplasty was significantly associated with reduced rates of revision surgery ($p < 0.001$). The rate of notchplasty in the failure group was 4.7 % (2/42) and the rate of notchplasty in the non-failure group was 36.9 % (31/84).

3.5. KT-1000

At a 2-year follow-up, Koga et al.[22] reported those who underwent notchplasty had an operative side to nonoperative side (STS) difference using the KT-1000 of 0.4 ± 1.3 mm and those without a notchplasty demonstrated 1.2 ± 1.3 mm ($p < 0.0017$). Neither group possessed a measurement greater than 5 mm; however, 6 patients in the notchplasty group had an STS measurement less than -2mm compared to 1 patient in the control group ($p = 0.048$). Pape et al.[19] reported no differences in KT-1000 STS measurements at a 1-year follow-up. Muneta et al.[20] did not provide values for KT-1000, but did state there was not a significant difference between notchplasty and non-notchplasty groups.

3.6. Extension deficits

When evaluating patients who received notchplasty versus those who did not, Pape et al.[19] noted an insignificant difference in the number of patients who developed an STS extension deficit of more than 10° at a 1-year follow-up. Koga et al.[22] found that notchplasty was significantly associated with increased rates of perceived limited extension at 1 and 2 years post-op ($p = 0.03$ and 0.011). They also found a significantly greater loss of extension at 1 year post-op in the notchplasty group compared to the non-notchplasty group (1.1° ± 1.4° vs 0.6° ± 0.8°, $p = 0.0054$), and again at 2 years post-op (0.9° ± 1.2° vs 0.4° ± 0.7°, $p = 0.0053$).

3.6.1. Patient reported outcomes

The three studies that evaluated Lysholm score did not report any significant differences between groups.[19,20,22]

3.7. Complications

Muneta et al.[20] reported chronic synovitis in 2/32 (6.3 %) knees that did not undergo notchplasty and none that had notchplasty. Pape et al.[19] did not find evidence of arthrofibrosis in either group. Koga et al.[22] reported 6 patients that required additional synovectomy in the notchplasty group, compared to 0 in the non-notchplasty group ($p = 0.0081$).

4. Discussion

The most important finding of this systematic review is that performing a notchplasty during primary ACLR is associated with similar PROMs and ACLR graft survivability compared to patients not receiving notchplasty.

Biomechanical studies in cadavers have shown that increased anterior tibial translation (ATT) is a risk factor for graft rupture and failure, after ACLR with notchplasty.[8,23–25] In contrast, Koga et al.[22] reported significantly decreased STS KT-1000 measurements in their notchplasty group. However, the decreased KT-1000 in this group may be secondary to postoperative arthrofibrosis from increased bleeding during notchplasty. Additionally, Pape et al.[19] and Muneta et al.[20] reported no difference between notchplasty and non-notchplasty groups regarding STS differences using KT-1000. All studies reported no patients in either group had an STS difference greater than 5 mm, a value historically used as a benchmark to judge graft success.[26–28] Therefore, none of these

Table 1
Study characteristics.

Author	Year Published	Study Design	Total Number of Patients	Number of Patients with Notchplasty	Number of Patients without Notchplasty	Follow-up Interval (months)
Muneta et al.[20]	1995	Retrospective Cohort	75	11	32	26.8
Pape et al.[19]	2001	Prospective Cohort	58	21	37	12
Thompson et al.[21]	2022	Retrospective Cohort	126	33	93	36
Koga et al.[22]	2014	Prospective Cohort	137	64	73	24

Table 2
Patient demographics.

Author	Females	Males	Average Age (years)	Graft Used (Number of Patients)			
				QT	BTB	Hamstring	Allograft
Muneta et al.[20]	39	36	23.5	19	0	56	0
Pape et al.[19]	17	41	28.8	0	58	0	0
Thompson et al.[21]	27	99	21.8	0	3	120	3
Koga et al.[22]	82	55	24	0	0	137	0

QT (Quadriceps Tendon) **BTB** (Bone-patellar tendon-bone)

Table 3
Outcomes.

Author	Graft Failure		[b]KT-1000		[b]Loss of Extension		Lysholm Score		Complications	
	Notchplasty	Non-Notchplasty	Notchplasty	Non-notchplasty	Notchplasty	Non-notchplasty	Notchplasty	Non-notchplasty	Notchplasty	Non-notchplasty
Muneta et al[20]	‡No difference between groups		[c]No difference between groups		‡No difference between groups		[c]No difference between groups		No chronic synovitis	Chronic synovitis in 2/32 knees
Pape et al[19]	–	–	<3 mm: 11 patients 3.5–5 mm: 8 patients ≥6 mm: 1 patient	<3 mm: 19 patients 3.5–5 mm: 12 patients ≥6 mm: 3 patients	4.7 % of patients developed STS LOE >10°	2.7 % of patients developed STS LOE >10°	"moderate" (70–79): 1 patient "good" (80–89): 10 patients "very good" (90–100): 9 patients	"moderate" (70–79): 4 patients "good" (80–89): 19 patients "very good" (90–100): 11 patients	No arthrofibrosis reported in either group	
Thompson et al[21]	*Notchplasty was performed in 2 of 42 cases of ACLR graft failure, and in 31 of 84 control patients that did not require revision surgery		–	–	–	–	–	–	–	–
Koga et al[22]	3/64 (4.6 %) patients experienced graft rupture	1/72 (1.3 %) patients experienced graft rupture	[a]Mean: 0.4 ± 1.3 mm >5 mm: 0 patients [a]<-2 mm: 6 patients	[a]Mean: 1.2 ± 1.3 mm >5 mm: 0 patients [a]<-2 mm: 1 patient	**1 year follow up** [a]*Mean STS LOE*: 1.1° ± 1.4° **Perceived LOE*: 8 patients rated "somewhat limited" 6 patients rated "very limited" **2 year follow up** [a]*Mean LOE*: 0.9° ± 1.2° [a]*Perceived LOE*: 4 patients rated "somewhat limited" 5 patients rated "very limited"	**1 year follow up** [a]*Mean STS LOE*: 0.6° ± 0.8° **Perceived LOE*: 6 patients rated "somewhat limited" 1 patient rated "very limited" **2 year follow up** [a]*Mean LOE*: 0.4° ± 0.7° [a]*Perceived LOE*: 2 patients rated "somewhat limited" 0 patients rated "very limited"	Mean: 94.4 ± 7.1	Mean: 95.7 ± 4.8	[a]6 patients required additional synovectomy	[a]0 patients required additional synovectomy

STS=Side to Side, **LOE**=Loss of Extension.
[a] Significant values.
[b] Values reported as operative leg minus unaffected leg.
[c] No data reported in text, states no difference between groups.

patients would have been assessed as "graft failures".

Despite biomechanical studies showing increased ATT, there was no significant difference in failure rates between groups, with one study reporting that notchplasty was significantly associated with reduced rates of ACL revision surgery.[21] This highlights the discrepancy between biomechanical model expectations and the actual survivorship of ACLR after notchplasty. There is no clear explanation for this discrepancy, especially when it has been proposed that excised bone regrows after notchplasty. However, this proposal may not be accurate as Kitridis et al.[29] found no significant bone regrowth after ACLR with notchplasty at a 2-year follow-up.

Although retear and failure rates of the ACL graft appear to be similar between those with notchplasty and those without, more patients appear to suffer from loss of extension (LOE) after undergoing

notchpasty. Koga et al.[22] reported that a significant number of patients who underwent notchplasty during primary ACLR reported a subjective feeling of limited knee extension postoperatively. However, their findings were still less than the typical threshold of STS LOE of >5°.[30–32] When using a higher threshold of 10° STS difference, Pape et al.[19] found no difference between groups. Despite the reported increases in LOE, studies utilizing Lysholm score reported no difference in the perceived functionality of the knee between groups.[19,20,22]

Arthrofibrosis and chronic synovitis are complications of joint surgery that limit joint function and often require repeat surgery to remove inflamed and fibrotic tissue.[33] The included studies demonstrated disagreements between rates of repeated synovectomy and chronic synovitis after ACLR with notchplasty.[20,22] It is hypothesized that increased bleeding due to the excision of bone performed during notchplasty leads to higher rates of arthrofibrosis and subsequent revision procedures.[22] In contrast, Pape et al.[19] found no evidence of arthrofibrosis in the notchplasty group but did find a significantly increased total blood loss compared to those who did not undergo notchplasty. While there were disagreements between complication rates of ACLR with notchplasty, included studies still reported similar post-operative outcomes scores between notchplasty groups.

A previous systematic review on this topic was performed in 2017.[34] While two of the studies included in this review were also included in the previous review, the addition of two new studies nearly doubled the number of observed patients. Additionally, the previous review included biomechanical, cadaveric, and animal studies to draw conclusions concerning notchplasty. The current review evaluated clinical studies that included an internal control group.

This study is not without limitations. The largest limitation of this systematic review was the heterogeneity of studies regarding sample sizes and reported outcomes. This limited our ability to perform comparative statistics and provide significant values to support our conclusions. Furthermore, there is a limited number of papers in this review which limits the power of conclusions.

5. Conclusion

Patients who undergo notchplasty during primary ACLR have similar outcome scores and risk of graft failure compared to those who do not undergo notchplasty. Notchplasty patients may also be at a higher risk for loss of extension and chronic synovitis.

Consent statement

As this was a systematic review of published literature, there were no patients to consent.

Author's contribution

Maxx Harrell: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft; Clay Rahaman: Methodology, Validation, Resources, Writing-editing and reviewing; Dev Dayal: Formal analysis, Investigation, Data curation, Writing-editing and reviewing; Patrick Elliott: Validation, Investigation, Data curation, Writing-editing and reviewing Andrew Manush: Validation, Investigation, Data curation; Caleb Brock: Validation, Investigation, Data curation; Thomas Evely: Resources, Supervision, Project administration, Writing-editing and reviewing; Eugene Brabston: Resources, Supervision, Project administration, Writing-editing and reviewing; Aaron Casp: Resources, Supervision, Project administration, Writing-editing and reviewing; Amit Momaya: Resources, Supervision, Project administration, Writing-editing and reviewing

Ethical statement

This is a systematic review with no direct contact with patients or their data, so there was no potential to unethically treat patients or patient data.

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Declaration of competing interest

The following authors have the stated interests, all others have none to disclose: **Amit Momaya:** CONMED Corporation- Other Professional Activities; **Eugene Brabston:** EBSCO-Editorial or governing board, Link Orthopaedics-Paid consultant, Orthopaedic Design NA-Paid consultant; **Aaron Casp:** American Orthopaedic Society for Sports Medicine-Board or committee member, Arthrex, Inc-Paid consultant.

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