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Original Research

Ligament augmentation repair is broadly applied across different orthopaedic subspecialities: an ISAKOS international survey of orthopaedic surgeons

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ABSTRACT

Objectives: To evaluate how ligament augmentation repair (LAR) techniques are currently used in different anatomic regions in orthopaedic sports medicine, and to identify the most common indications and limitations of LAR.

Methods: We sent survey invitations to 4,000 members of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine society. The survey consisted of 37 questions total, with members only receiving some branching questions specific to their area of specialisation. Data were analysed using descriptive statistics, and the significance between groups was evaluated using chi-square tests of independence.

Results: Of 515 surveys received, 502 were complete and included for the analysis (97% completion rate). 27% of respondents report from Europe, 26% South America, 23% Asia, 15% North America, 5.2% Oceania, and 3.4% Africa. 75% of all survey respondents report using LAR, most frequently using it for the anterior talofibular ligament (69%), acromioclavicular joint (58%), and the anterior cruciate ligament (51%). Surgeons in Asia report using LAR the most (80%), and surgeons in Africa the least (59%). LAR is most commonly indicated for additional stability (72%), poor tissue quality (54%), and more rapid return-to-play (47%). LAR users state their greatest limitation is cost (62%), while non-LAR users state their greatest reason not to use LAR is that patients do well without it (46%). We also find that the frequency of LAR use among surgeons may differ based on practice characteristics and training. For example, surgeons who treat athletes at the professional or Olympic level are significantly more likely to have a high annual use of LAR (20+ cases) compared to surgeons that treat only recreational athletes (45% and 25%, respectively, $p = 0.005$).

Conclusion: LAR is broadly applied in orthopaedics but its rate of use is not homogeneous. Outcomes and perceived benefits vary depending on factors such as surgeon specialty and treatment population.

Level of evidence: Level V.

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What are the new findings?

- Ligament augmentation repair is most frequently used for the anterior talofibular ligament, acromioclavicular joint, and anterior cruciate ligament.
- Ligament augmentation repair is most commonly indicated for additional stability, and the greatest reported limitation is cost.
- Surgeons who treat elite athlete populations use ligament augmentation repair more frequently than surgeons that only treat recreational athletes.
- Ligament augmentation repair use is not homogeneous and changes depending on surgeon training or treatment population.

1. Introduction

Complete ligamentous injuries can result in prolonged healing and recovery times before individuals are able to return to sport. In an effort to expedite postoperative recovery, ligament augmentation repair (LAR) devices have been introduced with the goal of stabilising the repair and offering earlier mobility. Historically, LAR devices such as the Ligament Advanced Reinforcement System [1,2] and the Kennedy–Ligament Augmentation Device [3] have been applied to common repairs such as the anterior cruciate ligament (ACL). In recent years, new LAR technologies made from braided ultra-high molecular weight polyethylene or interwoven fibre constructs have been applied more broadly across different anatomic regions to stabilise injured ligaments. In addition to "internal brace" constructs [4], many groups have introduced custom LAR constructs using different combinations of suture materials and anchors [5]. In this study, we broadly define LAR as a technique in which a suture material is used to support a ligament repair and is secured from bone to bone near the ligament origin and insertion. These ligament augmentation techniques (LATs) allow for reinforced repair strength during the healing process [4,6,7].

In recent years, the literature surrounding synthetic ligaments has grown rapidly with authors describing novel techniques for surgical implantation [8–11]. Internal brace stabilisation is frequently reported for injuries to the spring ligament complex [6,12], anterior talofibular ligament (ATFL) [7,13–17], deltoid ligament [18], ulnar collateral ligament (UCL) [19], lateral UCL [9], medial UCL [20], thumb UCL [21,22] ACL [23–27], medial collateral ligament (MCL) [28], posterior cruciate ligament [29], and coracoclavicular ligament [30,31]. New comparator studies of ATFL repair support that internal bracing can act as a useful complement to traditional repair procedures such as the Broström or Broström-Gould repair [13,14,32]. LAR may also pose a useful alternative to surgeries that would traditionally indicate reconstruction, particularly in the knee [4,29,33].

While the use of synthetic ligaments has been well reported in the literature for common anatomic regions, we believe current publications do not reflect the broad increase in the popularity of LAR and its application to less common ligamentous repairs that have not yet been published in the literature. The purpose of this investigation is to broadly characterise LAR's use among different anatomic regions and orthopaedic specialities to improve the awareness of LAR use-cases and guide future investigation on less common applications. We surveyed orthopaedic surgeons from various subspecialities regarding indications, outcomes, return to sport criteria, and use frequency in the context of ligament augmentation repair.

2. Methods

This survey was determined exempt from the review by our institutional review board as no subject identifying nor sensitive data was collected (COMIRB #20-1020). Participants were introduced to the study by email as a voluntary survey, and no incentive was provided for participation. IP addresses were not recorded to ensure anonymity. Survey data were collected and managed using REDCap electronic data capture tools hosted at the University of Colorado [34].

The survey consisted of 37 questions, several of which used branching logic and were only asked based on the respondent's background (i.e., only foot surgeons were asked if they use LAR on the ATFL). The survey questions fell into three general categories: 1) respondent demographics and training, 2) assessing the use of LAR, and 3) assessing the outcomes, complications, frequency, and benefit associated with LAR. Due to the broad definitions and use of commercially available and custom LAR constructs reported in orthopaedic literature, we surveyed respondents regarding the total LAR use. All members of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) society were sent an email inviting them to participate in the survey. The survey was first distributed on 12 January 2021 and the last survey was collected 6 June, 2021.

The data analysis was completed in the R statistical package (v. 4.1.0) [35]. Survey responses were tabulated and reported with frequencies and proportions. Chi-square tests of independence were used to assess the likelihood of any dependent relationships between respondent demographics and LAR use. In all cases, a p-value of less than 0.05 was considered significant. In order to run tests of independence between groups, demographic variables such as fellowship and treatment

Table 1
Survey respondent demographics.

		n	% Respondents
Survey Responses	Total	515	–
	Complete	502	97.5%
Location	North America	73	14.5%
	Europe	135	26.9%
	Asia	117	23.3%
	Africa	17	3.4%
	Australia/Oceania	26	5.2%
	Central America	6	1.2%
	South America	128	25.5%
Fellowship Training	Foot and Ankle	179	35.7%
	Hand/Upper-Ext.	39	7.8%
	Arthro/Joints	159	31.7%
	Sports	319	63.5%
	Trauma	96	19.1%
	Pediatrics	12	2.4%
	Other[a]	3	0.6%
	None	41	8.2%
Years Practicing	0–2 Years	33	6.6%
	3–5 Years	58	11.6%
	6–10 Years	64	12.7%
	11–20 Years	148	29.5%
	20+ Years	191	38.0%
	Retired	8	1.6%
Practice Setting	Academic Hospital	179	35.7%
	Private Practice	270	53.8%
	Community Hospital	52	10.4%
	Rural	0	0.0%
	Other	1	0.2%
Athlete Levels Treated	Recreational	434	86.5%
	High School	261	52.0%
	Collegiate	231	46.0%
	Professional	207	41.2%
	Olympic	80	15.9%
	No Athletes	33	6.6%
Industry Affiliation	Arthrex	64	12.7%
	ConMed	14	2.8%
	DePuy Synthes	29	5.8%
	Ethicon	2	0.4%
	Smith & Nephew	44	8.8%
	None of Above	371	73.9%
	Prefer Not Answer	32	6.4%

[a] In the "other" category for fellowship trainings, two respondents listed spine, one was unlisted.

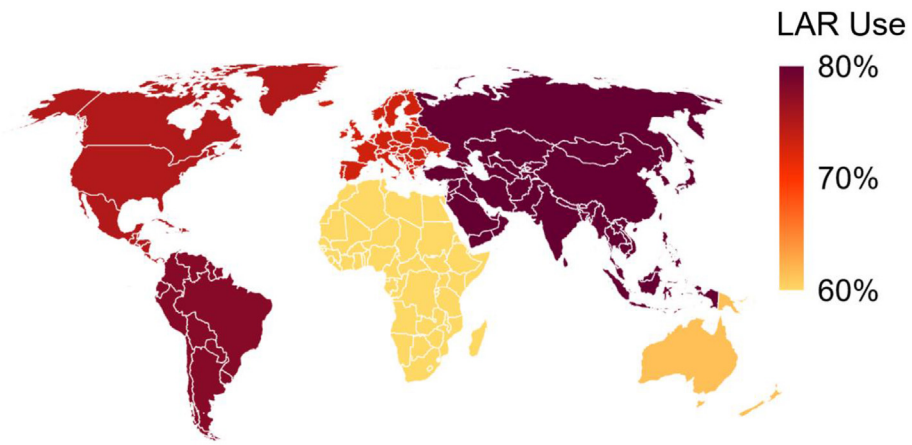

Fig. 1. The percentage of surgeon respondents that use LAR in each continent. Asia has the highest proportion of LAR users (80%, n = 117), followed by South America (78%, n = 128), North America (75%, n = 73), Europe (73%, n = 135), Oceania (62%, n = 26), and Africa (59%, n = 17). LAR, ligament augmentation repair

population were divided into mutually exclusive groups (Fig. S1 and Fig. S2).

3. Results

We collected 515 responses from ISAKOS surgeon members (approximately 13% of the total membership). 13 surveys were excluded because they were not complete, leaving 502 for analysis (97% completion rate). The survey reached a geographically diverse population of respondents, 27% from Europe, 26% from South America, 23% from Asia, 15% from North America, 5.2% from Oceania, and 3.4% from Africa (Table 1). 75% of all respondents reported that they use LAR. Asia and South America have the highest percentage of LAR users (Figure 1, 80% and 78%, respectively), while surgeons in Oceania and Africa use it the least (62% and 59%, respectively).

3.1. LAR use in specific body regions

Figure 2 shows the percentage of surgeons that use LAR for commonly treated ligaments in each major body region. Respondents only answered this question for the body regions they manage. 381 (76%) respondents answered for the knee, 307 (61%) for the foot and ankle, 218 (43%) for the shoulder, and 89 (18%) for upper extremities. In the foot and ankle, LAR is most commonly applied for the ATFL (69%), calcaneofibular ligament (CFL, 36%), and the deltoid ligament (34%). 46% of surgeons reported the use of augmentation techniques for the Achilles tendon. In the knee, LAR is most commonly used for the ACL, MCL, and the medial patellofemoral ligament (MPFL), at 51%, 46%, and 31%, respectively.

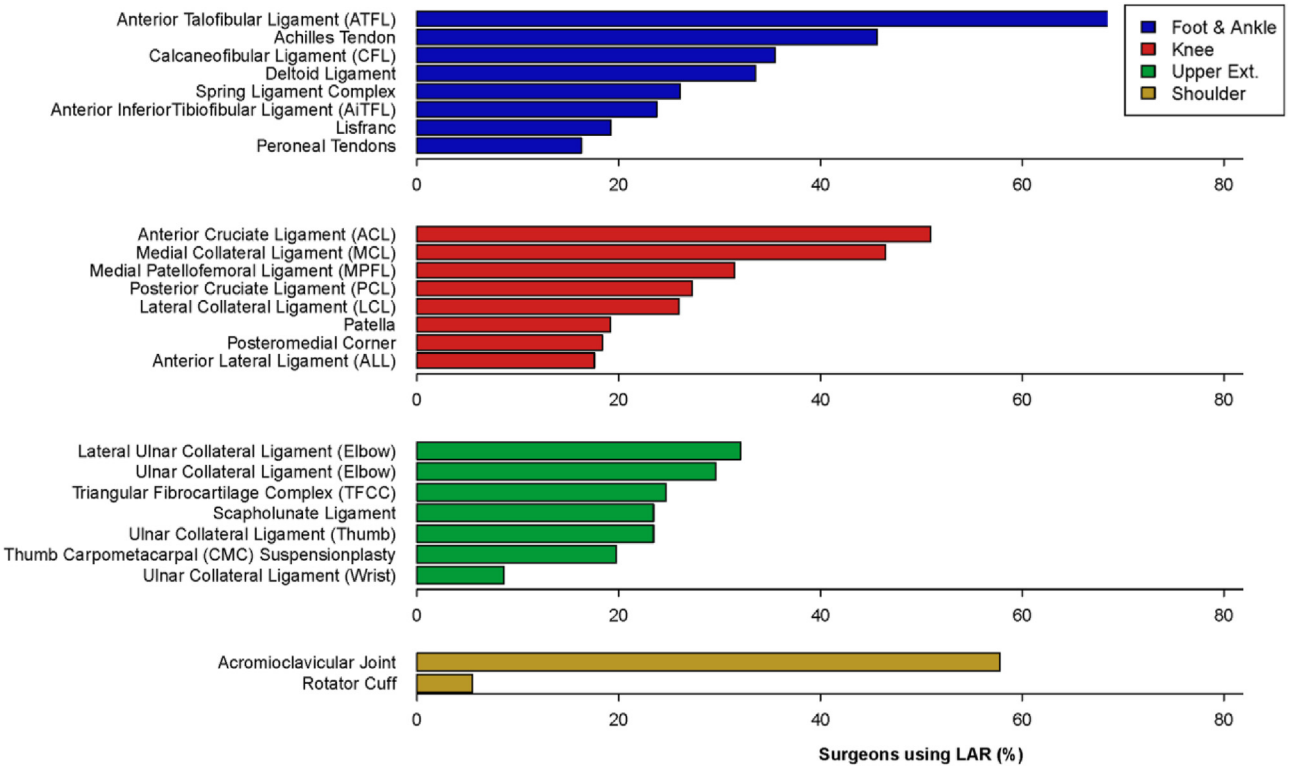

Fig. 2. The percentage of surgeon respondents that use LAR for specific ligaments or tendons in each body region. LAR, ligament augmentation repair

Table 2
LAR outcomes and use frequency.

		n	% respondents
Do you use LAR? (a)	Yes	378	75.3%
	No	124	24.7%
Percent of procedures using LAR? (b)	0%–10% Procedures	191	50.5%
	10%–25% Procedures	117	31.0%
	25%–50% Procedures	48	12.7%
	50–75% Procedures	14	3.7%
	75%–100% Procedures	8	2.1%
Procedures per year using LAR? (b)	0–10 Procedures	141	37.3%
	10–19 Procedures	103	27.2%
	20–29 Procedures	60	15.9%
	30–39 Procedures	33	8.7%
	40–49 Procedures	5	1.3%
	50+ Procedures	36	9.5%
Do patients benefit from LAR? (b)	Strongly believe patients benefit	94	24.9%
	Believe patients benefit	191	50.5%
	Neutral that patients benefit	82	21.7%
	Do not believe patients benefit	8	2.1%
	Waste of money	3	0.8%
What percentage patients have Good/excellent outcomes? (b)	90%–100% Procedures	122	32.3%
	80%–89% Procedures	151	39.9%
	70–79% Procedures	47	12.4%
	60%–69% Procedures	16	4.2%
	50%–59% Procedures	8	2.1%
	0%–50% Procedures	13	3.4%
	Prefer not answer	21	5.6%
What percentage patients have complications? (b)	0%–10% Procedures	320	84.7%
	10%–20% Procedures	27	7.1%
	20%–30% Procedures	11	2.9%
	30%–40% Procedures	2	0.5%
	40%–50% Procedures	1	0.3%
	50%–100% Procedures	1	0.3%
	Prefer not answer	16	4.2%

(a) Asked to all respondents, (b) asked to respondents who use LAR.
Abbreviations: LAR, ligament augmentation repair.

LAR is commonly applied in the shoulder and upper extremities, with the most frequent use in the acromioclavicular joint (58%), the lateral UCL (29%), and the elbow UCL (27%). A full table of these findings is available in the supplementary information (Table S1).

3.2. Outcomes and limitations of LAR

The majority of respondents who have used LAR either believe or strongly believe LAR is beneficial for their patients (25% strongly believe, 51% believe). 32.3% of respondents report that >90% of their procedures have good to excellent outcomes, and 39.9% report that 80–89% of their procedures have excellent outcomes (Table 2). 85% of respondents estimate that <10% of their procedures using LAR have a complication. LAR is most commonly indicated for additional stability (72%), poor tissue quality (54%), and more rapid return-to-play (47%). For LAR users, cost is the most common limitation, reported by 62% of respondents as a reason they "sometimes cannot use it" or "do not use it more." Non-LAR users report they do not use LAR because their patients do well without it (46%) and they do not perceive a benefit (40%). Cost is only reported as a limitation by 23% of non-LAR users as a limitation (see Table 3).

Table 3
Indications for and limitations of LAR.

		n	% Respondents
What are your reasons/ indications for use? (b)	Fellowship training	53	14.0%
	Patient request	29	7.7%
	Facilitates a more rapid return to activity	178	47.1%
	Provides additional stability	272	72.0%
	I use it for poor tissue quality	206	54.5%
	Multiple ligament involvement	165	43.7%
What are the limitations of LAR? (b)	Not always beneficial or necessary	148	39.2%
	Cost	236	62.4%
	Mostly use LAR in patients with poor tissue quality	144	38.1%
	Mostly use LAR in revision cases	121	32.0%
	Hospital/health system will sometimes not allow me	42	11.1%
	Not covered by insurance	61	16.1%
Why do you not use LAR? (c)	No benefit	49	39.5%
	Cost	29	23.4%
	Adds to complication risk	30	24.2%
	Hospital/health system will not allow me	17	13.7%
	LAR implants are not available in my country	7	5.6%
	LAR implants are too expensive	25	20.2%
	Cultural opposition	1	0.8%
	My ligament repairs are strong enough	36	29.0%
	My patients do well without these	57	46.0%

(b) asked to respondents who use LAR (c) asked to respondents who do not use LAR.
Abbreviations: LAR, ligament augmentation repair.

3.3. Use factors associated with physician or practice characteristics

Cross-tabulating demographic variables and outcomes (e.g., fellowship vs. perceived benefit), we found several statistically significant relationships. As shown in Fig. 3, foot and ankle fellowship-trained surgeons are significantly more likely to use LAR (87% use LAR) compared to both sports fellowship-trained surgeons (67% use LAR, $p = 0.002$) and surgeons without a fellowship (66% use LAR, $p = 0.01$). Foot and ankle fellowship-trained surgeons are also significantly more likely to believe that LAR is useful (85% believe) than sports fellowship-trained surgeons (67% believe, $p = 0.014$, Fig. S3).

We found that surgeons who treat athletes at the professional or Olympic level are significantly more likely to have a high annual use of LAR (20+ cases) compared to surgeons that treat only treat recreational athletes (45% and 25%, respectively, $p = 0.005$, Fig. S4). Furthermore, our survey demonstrated that surgeons with an industry affiliation to one of the five surveyed companies (Table 1) are significantly more likely to use LAR than surgeons who reported no affiliation (83% and 73%, respectively, $p = 0.049$, Fig. S5) and are significantly more likely to have a high caseload of LAR (54% and 30% respectively, $p = 0.0004$, Fig. S6).

4. Discussion

LAR is a stabilisation technique that is rapidly increasing in popularity among orthopaedic surgeons. This survey provides an insight into

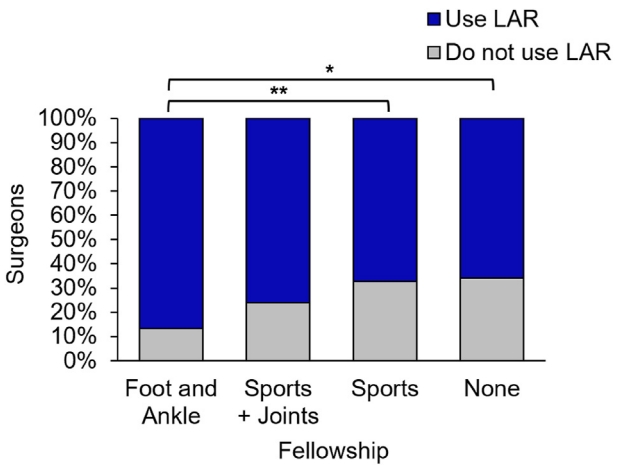

Fig. 3. The percentage of surgeon respondents that use LAR in different fellowship specialities. Chi-square tests of independence indicate a significant dependent relationship between fellowship and LAR use comparing A) foot and ankle vs. sports trained surgeons ($p = 0.0017$) and B) foot and ankle surgeons vs. surgeons with no fellowship ($p = 0.011$). Please see Fig. S1 in the supplementary information for how fellowship responses were divided into exclusive groups. LAR, ligament augmentation repair

the current uses and outcomes of LAR among different orthopaedic subspecialities. Of 502 respondents, 378 (75%) report that they use LAR. We found that LAR is used broadly among different subspecialities and body regions.

4.1. LAR use by extremity region

Assessing LAR use for ligament-specific repairs in each body region, our survey data help identify where future clinical outcomes research is most needed. In the foot, e.g., our survey data show LAR is commonly applied in the ATFL (69%) and the CFL (36%). While there are several clinical studies published assessing the role of LAR in ATFL stabilisation [13,14,32], there is little literature published describing LAR use for the CFL. Similarly in the upper extremities, while there are clinical outcome data published for LAR use in the elbow and thumb UCL [9,19-22] (used by 27% and 21% of surgeons, respectively), there are little outcomes data on LAR for scapholunate ligament repairs [36], despite it also being used by 21% of surgeons. In the knee, the ACL [23-27], MCL [28], and posterior cruciate ligament [29] (used with LAR by 51%, 46%, and 27% of respondents, respectively) have recent outcomes data published, but the LCL (used by 26%) has only been described as a technique [37]. Although several biomechanical studies have been published for both the CFL [38–40] and the scapholunate [41], early outcomes data are needed before a complete understanding of the outcomes and potential complications associated with these procedures is available. We also find that methods of direct and indirect ligament augmentation vary depending on the biomechanics of the anatomic site. For example, while anchor-based augmentation constructs are frequently applied for primary ligament repairs such as the ATFL [42], similar augmentation is achieved utilising button fixation in regions such as the AC joint [43].

4.2. Outcomes and Complications with LAR

Respondents report LAR use is associated with good, but not perfect, outcomes. While 32% of respondents report that 90%–100% of their procedures have good to excellent outcomes, a larger group (40% of respondents) reports that only 80%–89% of their procedures have good to excellent outcomes. These findings are consistent with early outcomes reported in the literature. In the ACL, early studies report satisfactory outcomes in 82% [23] to 93% [26] of patients. Using augmentation for UCL repair in overhead athletes, another recent study finds 111 patients 102 (92%) return to the same level of play with favourable outcomes [19]. A combination of Broström and internal brace results in favourable outcomes and return to sport for 86.4% of patients [17]. However, it is important to note that while these studies offer promising early outcomes, internal bracing is a relatively new technique, and few long-term outcome studies are available.

In addition to positive outcome rates, respondents also generally report low complication rates. The vast majority of respondents (85%) reported that less than 10% of their procedures have complications. We found no statistically significant difference in reported complications or outcomes between fellowship subspecialities. Current literature suggests that synthetic ligaments promote colonisation of fibroblasts, which may allow for greater biocompatibility of the augmented ligament to the host and reduce complications [44]. However, it is again important to note that due to the young age of this technology, a full understanding of potential complications may not yet be available. Cho et al. note that the elongation of lateral ankle ligaments after modified Broström has historically been cited as a potential source of complication, and further follow-up is required to understand the longevity of synthetic augmentation [45]. Additionally, there is currently insufficient literature available to determine if modern polyethylene LAR devices act by stimulating tissue growth in the area of augmentation or if they act exclusively through reduced mechanical stress.

4.3. Reported limitations of LAR

One intriguing finding from our survey is that the reported limitations of LAR differ between LAR users and non-LAR users. Current LAR users state the greatest limitation by far is cost (62%). The second greatest reported limitation is that it is not always necessary, reported by greater than one third of the respondents (39%). For non-LAR users, the greatest reason for not using this technique is that their patients do well without them (46%) and there is no perceived benefit (40%). Cost, comparatively, is ranked low by non-LAR users as a limitation, with only 23% reporting cost. These findings suggest that there are currently two barriers that shape LAR use in orthopaedics. The first barrier, limiting any use, is perceived benefit. Among surgeons who use LAR, the second barrier, limiting increased use, is cost. Cost may also play a larger role in specific regions. For example, while 23% of all non-LAR users report cost as a limitation, 41% of non-LAR users from Oceania and Africa report cost as a barrier. While our survey does not directly assess the barriers associated with cost, it is possible increased shipping or licensing costs are one reason for lower LAR utilisation in regions such as Oceania and Africa. Additionally, while we found that 75% of respondents use LAR, the majority (51%) currently use LAR for less than 10% of cases. Our findings support that decreased cost and increased perceived benefit are both important for future LAR utilisation.

4.4. Indications and perceived benefits of LAR use

Perhaps the most commonly published potential advantages of LAR are decreased postoperative immobilisation and a quicker return to sport [7,9,13,14,19,21,22,25]. When asked of the benefits or indications for LAR, respondents reported additional stability (72%), poor tissue quality (54%), and more rapid return-to-play (47%). This is consistent with several reports in the literature that LAR may allow quicker mobilisation due to secondary stabilisation. Studying suture tape augmentation of the ATFL, Martin et al. also note high patient satisfaction along with early rehabilitation [7], and the survey results show that 7.7% of surgeons even report having used LAR due to patient request. Recent biomechanical studies support that internal bracing provides additional stability over only a repair or reconstruction without augmentation [46–48]. One notable finding from our survey is that the percentage of surgeons who have a high caseload of LAR procedures (20+ surgeries per year) is significantly higher in surgeons who treat professional/Olympic athletes (45%) compared to surgeons whose highest-level athlete is

recreational (25%, p = 0.005). This suggests that there may be some association between the level of athlete treated and the level of LAR use, given LAR is commonly indicated for quicker return to play.

4.5. Differences in LAR use among subspecialities

In our analysis, we also found foot and ankle fellowship-trained surgeons use LAR significantly more (87%) than sports fellowship-trained surgeons (67%). Foot and ankle surgeons also perceive a greater benefit from LAR than sports surgeons (85% vs. 67%, respectively). Assessing these findings, it is worthwhile to point out the differences in history ligament augmentation has had in both disciplines over the last few decades. While augmentation to the ATFL or deltoid in the foot is somewhat a new technique, early augmentation capabilities such as the Kennedy Ligament Augmentation Device have been used in the ACL by knee surgeons since the early 1990s [49,50]. While the Kennedy LAD fell out of favour due to the risk of repeat surgery for effusions and pain, it is worthwhile to consider how historical LAR use may influence the adoption of modern internal bracing by physicians today. In addition to the success rate and indications, subspecialities may also inadvertently vary in acceptance due to the success, or failure, of similar techniques in the past.

5. Limitations and Future Directions

The broad scope of this survey comes with limitations and possibilities for future research. As alluded to in the last paragraph, one confounding factor is the broad definition that LAR, or particularly, "augmentation," can have among groups. In an effort to better understand the influence of different synthetic materials and fixation methods such as anchor and button constructs on the success of ligament augmentation, our group is publishing a systematic review of all LATs in orthopaedic literature intended to provide stabilisation to disrupted ligaments [51]. We have broadened our systematic review to LATs, opposed to LARs, to provide a more wholistic picture of augmentation techniques as they are referred to and understood by surgeons clinically, including stabilisation of ligaments in the syndesmosis or AC joint using synthetic suture constructs. This systematic review will also help better understand how indications and complications vary across different anatomic regions. Future surveys may provide more granularity by parsing out use frequency and benefits for specific LAR devices. As members of the ISAKOS membership were invited to participate in a survey regarding augmentation, it is also possible selection bias influenced the ratio of LAR users to non-LAR users we found. While we collected data on the use of LAR in each ligament in alignment with surgeon subspeciality, outcomes and complications were generalised to all LAR cases the surgeon performs. When estimating the number of cases with complications, it is also difficult to distinguish if these complications are specifically associated with ligament augmentation. In the future, we intend to disseminate focused surveys limited to one subspeciality that will provide a more specific picture of the technical considerations and outcomes associated with augmentation for each ligament.

6. Conclusions

Augmented ligament repair techniques are a growing component of the orthopaedic sports medicine landscape. This survey suggests that LAR is a part of orthopaedic practice broadly around the world in all major joints and extremities. Although there is a comparable level of literature outcomes for some regions where LAR is reportedly used, other ligament-specific repairs would benefit from greater representation in clinical literature. Augmented stabilisation and more rapid rehabilitation and return-to-play suggest that LAR techniques hold tremendous potential in the care of athletes at all levels.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jisako.2023.04.004.

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