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ORTHOPAEDIC SURGERY

Current status of ACL reconstruction in Germany

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Abstract
Introduction Reconstruction of the anterior cruciate ligament (ACL) is characterized by a variety of possibilities concerning its implementation. Different choices for grafts, fixation methods and tunnel positioning, as well as diverse technical tools are available and have clinical significance. Besides specific pre- and post-operative procedures, different indications for surgery and further surgeon-/clinic-related factors add variability to the treatment. In response to the lack of descriptive statistics about the implementation of these factors and the increasing numbers of ACL reconstructions this study has been conducted to display the current state of the treatment for ACL tears throughout Germany.
Materials and methods 709 clinics with surgical and orthopedic departments were provided an online-questionnaire that surveyed their statistical records (e.g. annually implemented operations, number of surgeons, duration of operations), implemented techniques (e.g. choice of grafts, construction of drilling tunnel, tibial/femoral fixation) and personal assessment (e.g. frequency/cause of graft failure, frequency/handling of infection). The response rate was 22 % ($n = 155$). Based on the statistical records a specialized group within the respondents was identified, enabling a cross-comparison between high- and low-volume surgeons.
Results On average, the German orthopedic surgeons in the clinics surveyed annually performs 35 ACL reconstructions, with each operation lasting an average of 67 min. After subdividing the data with references to annually performed surgeries into high- and low-volume-surgeons, differences and common features between the subgroups become apparent. Differences between high- and low-volume-surgeons, respectively, show shorter duration of both ACL reconstructions (55 vs. 71 min) and revision ACL reconstructions (75 vs. 90 min), higher membership rates in professional associations (83 vs. 38 % have at least one membership), more frequent implementation of stability examinations (47 vs. 21 %) and different frequencies of femoral drilling techniques (using the anterolateral portal in 71 vs. 54 %). With reference to evaluating operation dates, choosing grafts and assessing reasons for graft failure both groups share commonalities, as well as regarding the predominant use of monofixation for femoral fixation (88 % of the participants—mainly with endobutton in 38 % and transfixation pin in 27 %) and for tibial fixation (81 % of the participants—mainly with bioabsorbable screw in 60 %).
Conclusions The treatment of ACL tears in the group of German clinics studied is characterized by a variety of surgical possibilities. This condition might reflect the entirety of clinics reconstructing ACL in Germany. For the first time, a descriptive statistical survey was implemented to display this variety and to provide insight into the current status quo. Within the entirety of surgeons implementing ACL reconstruction a specialized subgroup with a particular expertise seems to exist.

Keywords Current status · ACL reconstruction · ACL revision · ACL infection · Clinical practise

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Introduction

Since the implementation of arthroscopic assisted anterior cruciate ligament (ACL) reconstruction in the 1980s [1], different developments led to the current status quo, in which the ACL reconstruction represents the generally accepted therapy for the treatment of knee instability after ACL rupture.

Whether an operation defers or prohibits the occurrence of osteoarthritis [2] is still controversially discussed. However, many studies distinctly reveal that derivative defects of cartilage and menisci are consequences of a missing treatment of the rupture [3]. Accordingly, the purpose of the ACL reconstruction, regenerating the knee's stability and kinematic chain to regain activity in everyday life and sports, has not changed over the years.

Until today an ever-increasing number of ACL reconstructions is registered. This augmentation is based on an improvement of diagnostics and outcome, but also on a change of leisure and sports behavior, which leads to a rise in registered injuries [4].

Although the fundamental technical principle of ACL reconstructions has not been altered for years—threading a primarily autologous graft with solid fixation in an anatomically well-positioned femoral and tibial drilling tunnel—hardly any other muscular/skeletal injury is scientifically studied so thoroughly. Just in 2014 PubMed listed 1313 new publications dealing with the ACL.

Today there are a number of diverse possibilities to reconstruct the ACL. The use of different allogenic and autologous replacement materials, various techniques for the fixation of the graft, different possibilities for the positioning of the drilling tunnel, and varying postoperative care predominantly result in good outcomes [5–7]. Even though various anatomic, biomechanical, and clinical studies illustrate the advantages and disadvantages of each surgical technique, none of these expose significant superiority [8–12].

Beside the fact that many possibilities for a successful ACL reconstruction exist literature offers little information about effective applications of different therapeutic methods in day-to-day work.

Considering the lack of descriptive statistics, a survey consulting German clinic, was implemented to gather the current state of treatment for ACL ruptures.

Methods

Using the software package Survey (https://www.soscisurvey.de/) in January 2014 an online-questionnaire concerning the diagnostics and therapy of ACL injuries was sent to 709 surgically and orthopedically working clinics in Germany. Two email reminders followed. The corresponding email addresses were ascertained from the German hospital Address register of 2012 (Dka/Rombach Verlag, 50, edition 2012) (http://www.dka.de).

The response to the questionnaire was kept anonymous so that the content did not include direct hints about the participating clinics. Containing 28 questions the survey is structured in two parts:

On one side, information about the number of annually implemented operations, the number of surgeons, the average duration of the operations, and the membership in professional associations were gathered. Based on these details, specialized groups within the respondents could be identified allowing a differentiated consideration of the responses and illustrating differences between high-volume-surgeons and low-volume-surgeons.

Furthermore, details about the implemented diagnostics and therapy, as well as complications were inquired. This included information about the knee's position during surgery, the choice of grafts, the construction of the drilling tunnel, the tibial and femoral fixation, as well as data about the frequency, cause, and handling of specific complications (graft failure, infection).

Capturing them in an excel-file the results of the survey were statistically analyzed. Correlation analyses were carried out with the help of PSPP (version 0.8.4).

Results

The online-questionnaire was sent to a total number of 709 clinics. It was opened 185 times and 155 participants replied to the survey (22 %). 57.5 % of the participating clinics stated a surgical focus of work, while 42.5 % stated an orthopedic one.

Frequency of implemented ACL reconstructions

The average number of implemented ACL reconstructions, stated by the heads of the participating departments, is 78 per year (range 0–1000). On average, 2.3 surgeons per clinic (range 0–10) operated on these injuries, each surgeon carrying out 35 operations annually (range 0–195). In Table 1 the frequency distribution of annually implemented ACL reconstructions, divided by the number of operations per clinic, is summarized. According to this distribution, the clinics can be categorized into different subdivisions.

Specialization

Based on the data in Table 1, displaying that an increasing annual number of implemented operations per clinic does

Table 1 Frequency distribution of anterior cruciate ligament (ACL) reconstructions per clinic

Annual number of ACL-reconstructions/clinic	0–10	11–50	51–100	101–300	>300
N	11	62	28	16	6
Percentage share (%)	8.9	50.4	22.8	13	4.9
Average number of surgeons per clinic	1.2	1.9	2.9	2	3.8
Annual number of ACL-reconstructions/surgeon	4.9	17	37.9	94.2	105.3

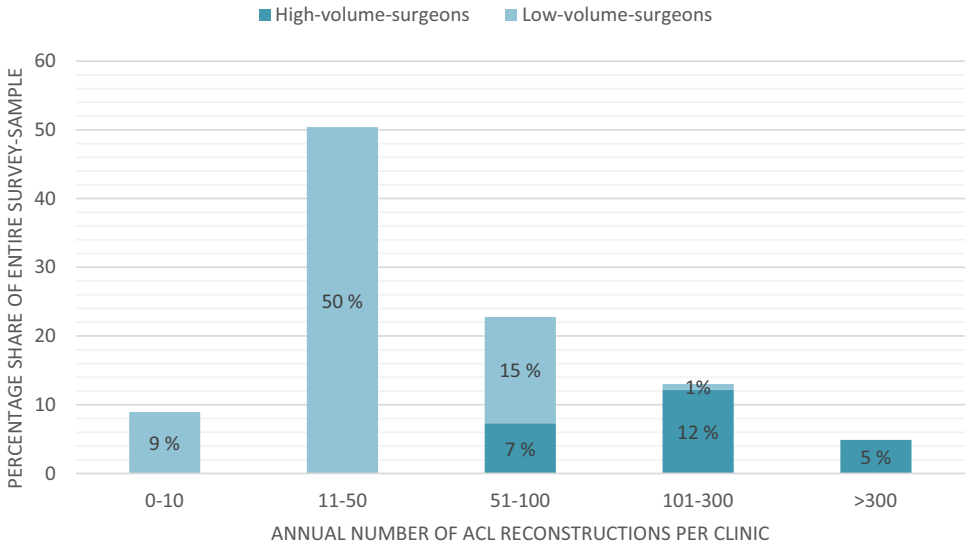

Fig. 1 Distribution of high- and low-volume-surgeons in clinics of different annual operation capacities

not lead to an appropriate rise in the number of surgeons, but to an increase in the number of operations per person, a distinction between high-volume-surgeons and low-volume-surgeons can be made. Accordingly, high-volume-surgeons are defined as clinics, in which the employed surgeons annually operate 50 or more ACL reconstructions per person.

The clinics that employ high-volume-surgeons (22 % of the surveyed departments) record exhibiting 200 surgeries per year on average a significantly higher annual number of operations ($P < 0.001$ *t* test) and exhibiting 96 surgeries per year and per surgeon a significantly higher annual operation number per person ($P < 0.001$ *t* test) in comparison to the clinics employing low-volume-surgeons (39 operations/year, 17 operations/year/surgeon). The diagram in Fig. 1 demonstrate the distribution of annual numbers of ACL reconstructions within the different subgroups.

While, in accord with the above-mentioned definition, there are no high-volume-surgeons in clinics with less than 50 annual operations, the subgroup almost entirely dominates the clinics with more than 100 surgeries each year.

Revision ACL reconstructions are operated appreciably less frequently in the surveyed clinics than ACL reconstructions. 13 revision ACL reconstructions are performed annually per clinic, whereby on average, each surgeon operates five patients each year. Separated by specification the clinics with high-volume-surgeons perform 35 revision ACL reconstructions on average compared to six operations in clinics with low-volume-surgeons ($P < 0.001$ *t* test). Hence, high-volume-surgeons complete 18 annual revision ACL reconstructions per person, while low-volume-surgeons merely perform two operations per physician ($P < 0.001$ *t* test) (compare Fig. 2).

Membership in professional associations

Based on the criteria for classifying two subgroups the results show that high-volume-surgeons seek membership in one or more joint-oriented professional associations significantly more frequently than low-volume-surgeons ($P < 0.001$ Chi square test). 83 % of the high-volume-surgeons have at least one membership in such an association (one membership 59 %, two memberships 14 %, three or more memberships 10 %). In contrast, only 38 % of the low-volume-surgeons are in at least one professional association. Despite those differences, both subgroups prefer the same associations in a similar manner (compare Fig. 3).

Indication for surgery

The evaluation (1 = major importance, …, 7 = least meaning) of various diagnostic treatments for the causal indications of an ACL reconstruction, are drawn equally

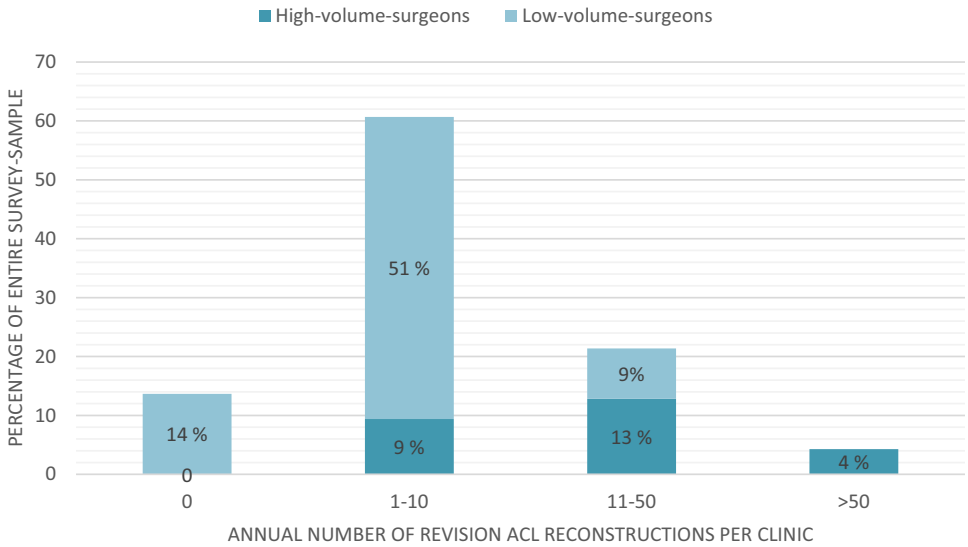

Fig. 2 Frequency distribution of revision ACL reconstructions dependent on degree of specialization

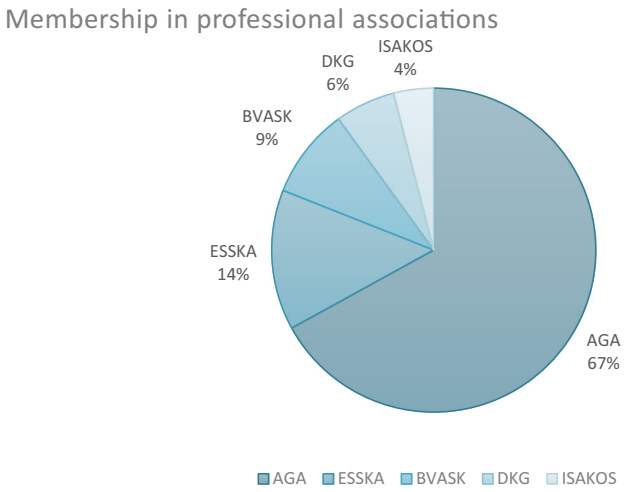

Fig. 3 Frequency distribution of memberships in professional associations (multiple choice)

between high- and low-volume-surgeons. The subjective instability of the patient is concordantly appraised as the most important criteria for the determination of performing surgery, followed by the Lachman test. The Pivot shift test, the anterior drawer test, and the MRI follow as equally evaluated diagnostic tools. Other means like stress radiography, are considered to be less important (compare Fig. 4).

Conservative vs. operative treatment

Surveyed about the ratio between the recommendations of conservative and operative treatment the results reveal a relation of 20–80 %. Ascertaining significant differences between the subgroups, the high-volume-surgeons advice to treat the injury conservatively in 13 % of the cases and thereby a little less than the low-volume-surgeons with 21 % ($P = 0.016$ t test).

Date of operation

Figure 5 illustrates a ranking concerning the ideal moment for the performance of a surgery (1 = ideal date for operation, …, 5 = least appropriate date for operation). An early elected date in the given period of time from 6 weeks to 3 months is the preferred choice. Although no distinct differences between high- and low-volume-surgeons are identifiable, high-volume-surgeons (average rank 1.9) evaluate the acute care more often as the best possible handling in comparison to low-volume-surgeons (average rank 2.8).

Out-patient vs. in-patient treatment

Without ascertainable differences among the subgroups, 95 % of the surveyed physicians state an in-patient surgery of the ACL. Merely 5 % operate out-patiently.

Position technique

Asking about the preferred technique of knee positioning the 75 % of the respondents (high-volume-surgeons 67 %, low-volume-surgeons 77 %) choose the hanging knee for ACL reconstructions. 20 % prefer operating in a lying/positioned technique, and 5 % use modified techniques (e.g. electric/hydraulic-adjustable knee crutches, dynamic knee braces, continuous passive motion).

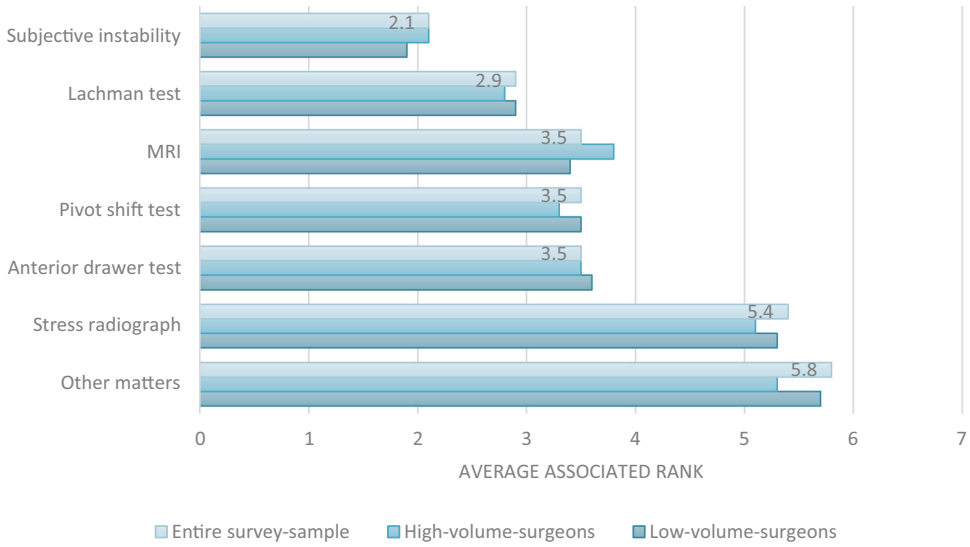

Fig. 4 Evaluation of diagnostic tools for the medical indication of an ACL reconstruction

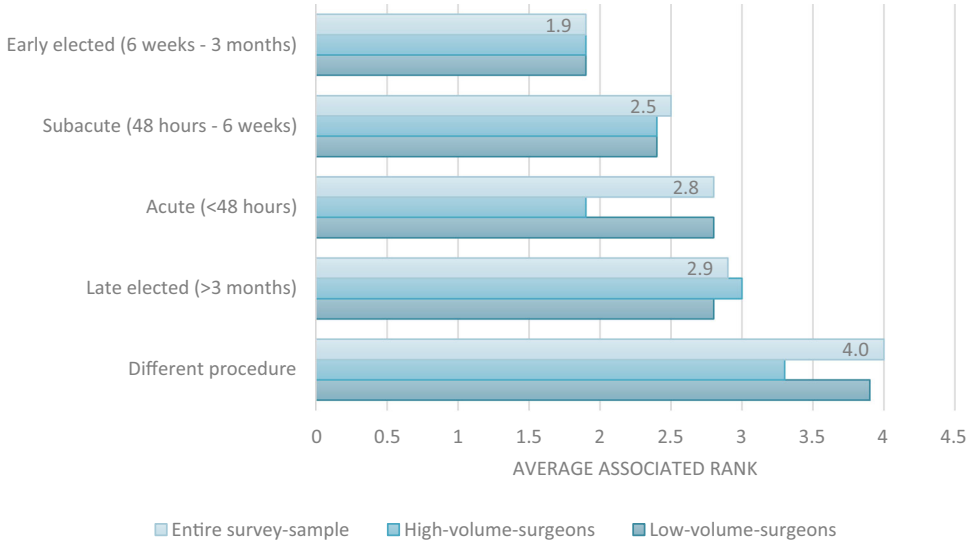

Fig. 5 Evaluation of optimal operation date for an ACL reconstruction

Arthrometer stability examinations

The performance of pre-, intra- and postoperative measurements of stability in the context of ACL reconstructions is rather low. Only 27 % of the surveyed surgeons implement stability measurements (17 % with the help of a Rolimeter, 10 % by using a KT1000, others 0 %). However, high-volume-surgeons apply arthrometer more frequently than low-volume-surgeons (47 vs. 21 %, $P = 0.008$ Chi square test). Surgeons, who perform such metering, most commonly measure preoperatively (86 %) or postoperatively (63 %). Only 17 % implement an intraoperative measurement after the fixation of the graft. Moreover, 55 % of the arthrometer-applying surgeons collect two or more readings.

Choice of grafts

Without distinct differences among the subdivided respondents, high- and low-volume-surgeons preferentially use the semitendinosus tendon respectively the semitendinosus tendon in combination with the gracilis tendon as graft for an ACL reconstruction. The second most common graft among the surveyed surgeons is the patellar tendon, followed by the quadriceps tendon. Allografts are used distinctly less frequently. As in the context of this study, only a ranking of the implemented grafts was inquired no distribution on percentage basis about the frequency of implemented grafts throughout the surgeries is possible (compare Fig. 6).

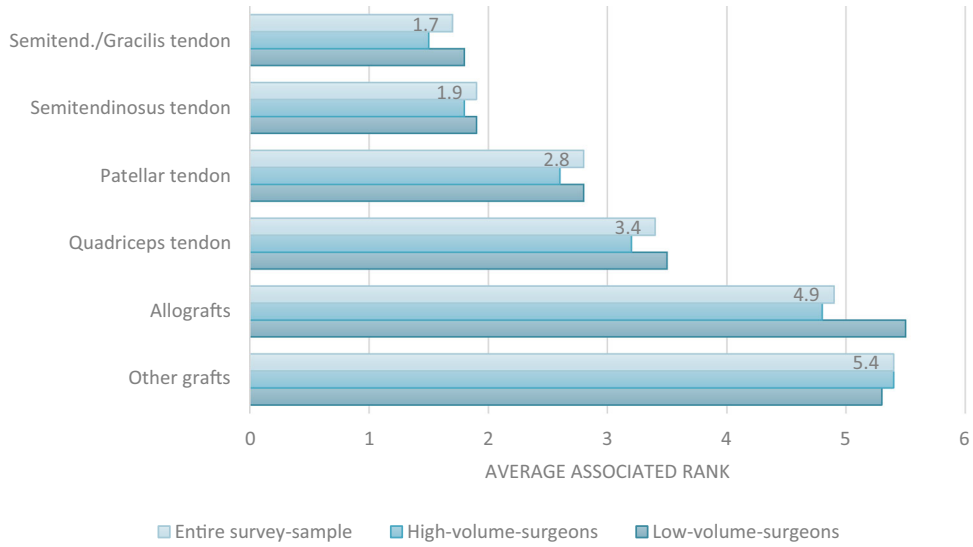

Fig. 6 Evaluated ranking of used grafts for an ACL reconstruction

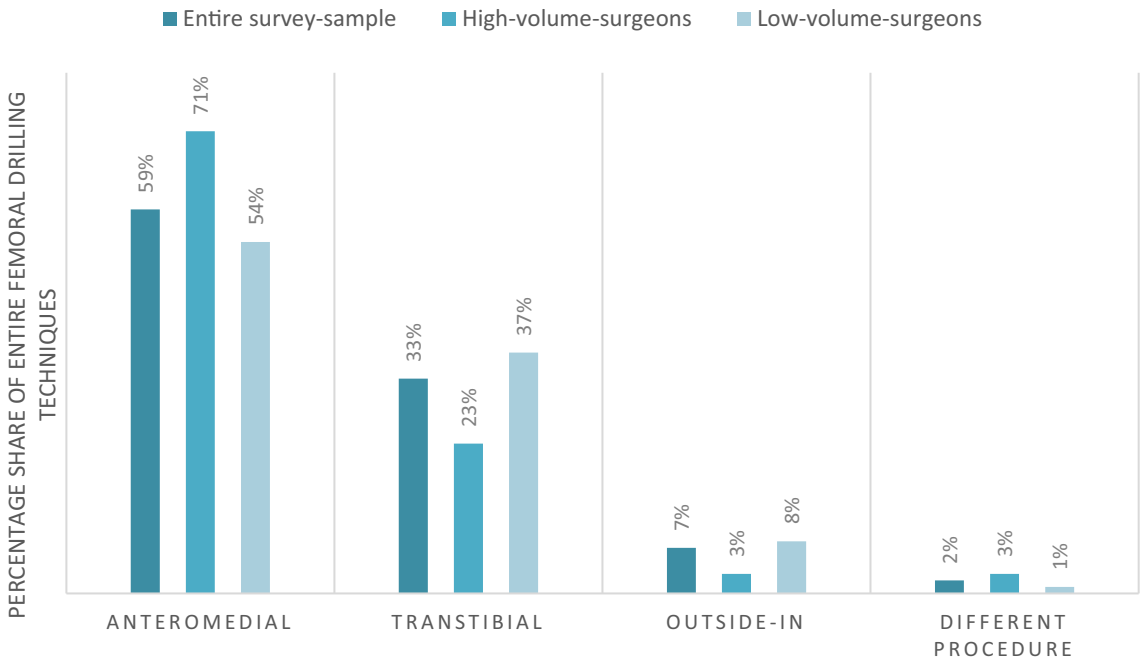

Fig. 7 Frequency distribution of femoral drilling techniques

Technique of the femoral drilling tunnel

The position of the femoral drilling tunnel using an anteromedial portal is the most commonly implemented technical method (59 %). However, differences between high- and low-volume-surgeons stick out (71 vs. 54 %). As well containing differences between high- (23 %) and low-volume-surgeons (37 %) the transtibial technique represents with 33 % on the entire average the second most commonly used method. The significance test based on a significance level of 5 % results in a *P* value of 0.072, making the differences insignificant. Nevertheless a connection has to be taken into consideration. Distinctly less often and without differences between the subgroups other methods like the outside-in technique are applied (compare Fig. 7).

Use of intraoperative fluoroscopic images for tunnel positioning

Fluoroscopic images during ACL reconstructions are made infrequently. Merely 12 % of the surveyed departments use

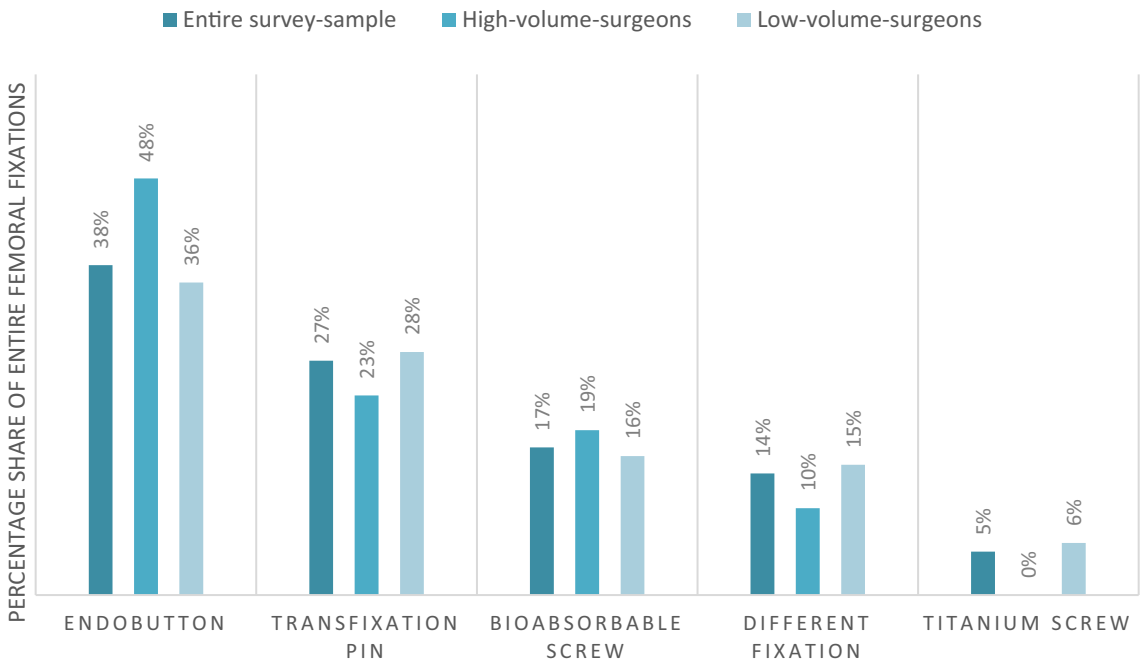

Fig. 8 Frequency distribution of different femoral fixation techniques

this intraoperative tool to control the tunnel positioning. Among the high-volume-surgeons imaging is only applied in 3 %. Consequently this technique is predominantly implemented by low-volume-surgeons, though the rate is also only 14 %.

Femoral fixation

Without significant differences between high- and low-volume-surgeons 88 % of the respondents choose monofixation and 12 % of the surgeons prefer a hybrid fixation. Also independent of the degree of specialization among the subgroups the tiltable plate (Endobutton, Smith & Nephew; Fliptac, Storz; Tightrope, Arthrex) represents the most frequently applied femoral fixation method for the graft, followed by transfix, and the bioabsorbable screw. Metallic screws and implant-free fixations are rather seldom (compare Fig. 8).

Tibial fixation

Analogous to the femoral fixation, the monofixation (81 %) illustrates the preferred technique in comparison to hybrid fixation (19 %). The bioabsorbable screw, applied by 60 % of the surgeons, is the most commonly used tool for fixating the graft. Accounting for a total of 17 % of the entire fixations the distant to the joint located fixation method with the help of titanium plates (Suture disc, Smith & Nephew; EndoTack, Storz; Tightrope ABS, Arthrex) are runner-up. In comparison to the femoral methods different fixations like knots by cortical screws/bridges and implant-free techniques are implemented more frequently (compare Fig. 9).

Duration of operation

Asking for the duration of an ACL reconstruction, the average length of a surgery equals 67 min. Significant differences between the subgroups ($P < 0.001$ t test) are discernible [high-volume-surgeons 55 min (range 30–100 min), low-volume-surgeons 71 min (range 21–150 min)]. In contrast to only 37 % of the low-volume-surgeons requiring less than 60 min for an ACL reconstruction, 90 % of the high-volume-surgeons finish the operation during the same amount of time ($P = 0.001$ Chi square test).

The average duration for a revision ACL reconstruction equals 86 min, also containing significant differences ($P = 0.001$ t test) depending on the degree of specialization [high-volume-surgeons 75 min (range 40–120 min), low-volume-surgeons 90 min (range 35–150 min)].

Frequency and cause of graft failure

Surveying about complications after ACL reconstructions the graft failure frequency is estimated equaling 14 %. Analyzing the significant difference ($P = 0.016$ t test) between high-volume-surgeons (10 %) and low-volume-surgeons (16 %), variations become visible. Among the

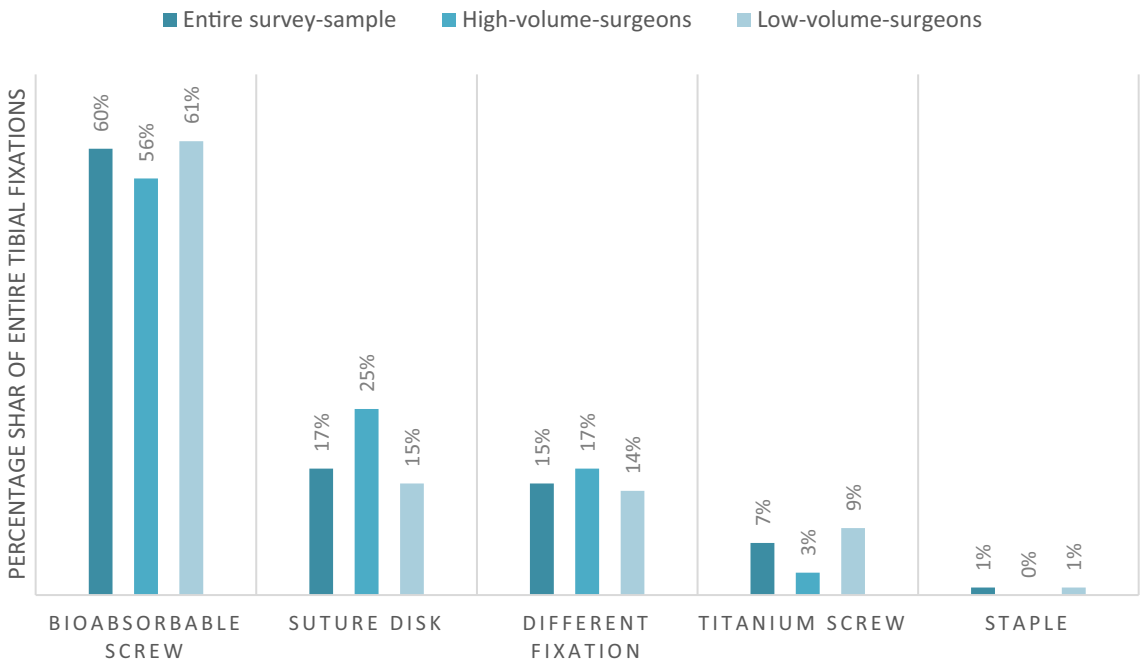

Fig. 9 Frequency distribution of different tibial fixation techniques

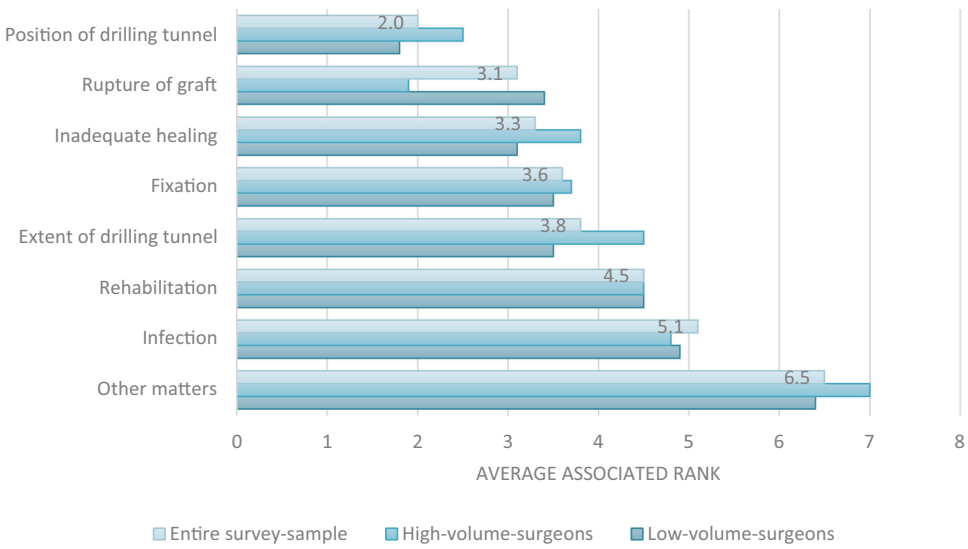

Fig. 10 Evaluated ranking of causes for graft failures after ACL reconstruction

own patient population, the frequency of graft failures is estimated to be lower (8 %). High-volume-surgeons (4 %) distinguish significantly ($P = 0.010$ t test) from low-volume-surgeons (10 %).

Evaluating the different causes of graft failure the incorrect positioning of drilling tunnels is rated as the most common reason. Following, other reasons for failure are stated in descending order: the traumatic-induced rupture of the graft, biological factors, and the failure of the fixation materials. The subgroups distinguish distinctly from each other in the assessment of the main cause for graft failure. While high-volume-surgeons interpret the graft rupture (average rank 1.9) as mainly responsible the low-volume-surgeons assume the position of the drilling tunnel (average rank 1.8) as more considerable for complications. Other distinct differences in the ranking of the influencing factors cannot be deduced (compare Fig. 10).

Frequency and treatment of infections after ACL reconstruction

The average infection rate after ACL reconstruction is estimated to equal 2.1 % (high-volume-surgeons 1.6 %, low-volume-surgeons 2.2 %) by the different surveyed departments, whereas the frequency among own patients is stated to be distinctly lower equaling 0.8 % (high-volume-surgeons 0.6 %, low-volume-surgeons 0.8 %). Significant differences between the subgroups are not reflected based upon the outcome of the survey.

Asking for the treatment of infections, 87 % of the responding clinics implement antibiotic treatment and multiple irrigations of the knee. In 11 % of the clinics merely a single irrigation in combination with antibiotics is treatment standard. Only 2 % of the clinics state an open revision plus antibiotics as their primary treatment for infections. The period of antibiotic treatment lies within 4–6 weeks among 76 % of the respondents. 17 % perform antibiotic treatment up to 2 weeks, 1 % up to 8 weeks, and 6 % up to 3 months. The probability of graft failure after an infection is estimated to equal 49 %. Between high- and low-volume-surgeons no significant differences regarding the treatment of infections and the risk assessment can be deducted.

Discussion

Based on the Germany-wide survey, the presented results display the status quo of diagnostics and treatment of ACL ruptures in Germany. Additionally, for the first time information about the frequency of implemented ACL surgeries in German clinics could be gathered. However, already at this point it must be emphasized that the results only consist of pure descriptive statistics. Consequently no conclusions or suggestions for a most advantageous therapy are inferable.

Unattached of the clinical work focus (surgical focus 57.5 %, orthopedic focus 42.5 %), the statistical results display that almost 60 % of all ACL reconstructions are implemented in clinics, in which 1–2 surgeons perform less than 17 operations annually. Indeed an increasing number of annual operations per surgeon is already ascertainable in clinics with 51–100 operations per year (37.9/year/surgeon), but a distinct increase is initially registered in clinics implementing more than 100 ACL reconstructions each year. In this share the average number of operations per surgeon amounts to almost 200 annually. Even though no studies exist regarding the topic of verifying the correlation between the amount of surgeries performed and result indicators for quality in ACL rupture surgery, it is commonly assumed that an increasing number of operations per surgeon influences the outcome of the operation [13]. Regarding this context, the non-proportional rise of surgeons in relation to the stronger increase of annual operations supports the assumption that specializations for ACL reconstruction within the surveyed departments exist. Serving as an evidence for the validity of the differentiation between high- and low-volume surgeons the membership in professional associations distinguish significantly between both groups. Similarly, the outstandingly shorter average duration of both ACL reconstructions (55 vs. 71 min) and revision ACL reconstructions (75 vs. 90 min) are an indicator for validity.

Sensitivity and specificity of different ACL-related radiologic and clinical examinations are well-known and studied [14–17]. Asking for the evaluation of clinical examinations regarding the appropriateness of an operation the major importance is ascribed to the subjective instability of the patient by both high- and low-volume-surgeons. Other criteria like the extent of instability in Lachman test or the radiologic detection of the rupture using MRI are subsequently taken into account, independent of the degree of specialization. Examinations with the help of arthrometers for the objective estimate of the rupture-induced instability are implemented less frequently. Without undermining the helpfulness of clinical tests and MRI for the therapy recommendation the surveyed evaluation indicates that individual ramifications of ascertained ACL damages are prioritized. Regarding to the results of the questionnaire respondents argue in favor of an ACL reconstruction 80 % of the time, whereby the operative solution is a little more frequently recommended by high-volume-surgeons.

In regards to an optimal timing for surgery after ACL rupture, different possibilities exist. The acute care competes with early elected respectively delayed strategies [18]. Uniform and evidence-based recommendations for the ideal operation date are missing. The results of the survey mirror the actual reality of treatment and display that an early elected date 6–12 weeks after the occurred rupture is the most commonly preferred option. More than a few surgeons also recommend subacute care (48 h to 6 weeks after trauma) respectively acute care (less than 48 h after trauma). Late elected dates for operations are relatively seldom.

As mentioned above, various techniques and modifications of ACL reconstructions exist regarding the preferred positioning, the choice of grafts, the fixation, and the technique of the drilling tunnel. The outcome of the survey outlines the distribution and frequency of implemented techniques and grafts in Germany. Furthermore, the results support the assumptions of different publications that soft tissue grafts are used preferentially in Germany [19, 20]. Regarding femoral fixations, the percentage share of mono

fixations prevails with 80 % compared to hybrid fixations with 20 %. In descending order, endobutton (38.1 %), transfixation pin (26.6 %) and bioabsorbable screws (16.5 %) are implemented. 60 % of the survey's respondents use the bioabsorbable screw as mono fixation for the tibial fixation. Specialization-dependent differences regarding the choice of grafts and the fixation are not inferable, but they emerge when asking about techniques for the femoral drilling tunnel. While more than 70 % of the high-volume-surgeons choose the anteromedial portal, merely 54 % of the low-volume-surgeons utilize this method, although advantages concerning the better possibility for an anatomic positioning using the anteromedial portal are well-known [21]. Besides the fact that 37 % of the low-volume-surgeons prefer a transtibial technique for the femoral drilling tunnel, it appears to be striking that at least 23 % of the high-volume-surgeons still utilize this option.

Considering the cause of graft failure, distinct differences between the subgroups are noticeable based on their evaluations. While low-volume-surgeons estimate the incorrect positioning of the drilling tunnels as the main reason for failure, high-volume-surgeons think that the trauma-induced anew rupture is the primary decisive factor. Moreover, regarding the general frequency of graft failure, differences are ascertainable. In this context, high-volume-surgeons estimate the frequency of graft failure to be significantly lower compared to low-volume-surgeons (10 vs. 16 %). Asking for the occurrence within their own patient population, the estimated frequency decreases significantly among both subgroups (high-volume-surgeons 4 %, low-volume-surgeons 10 %). Different causes respectively combinations of causes are held responsible for graft failure after ACL reconstruction. Even though high- and low-volume-surgeons evaluate the reasons for graft failure slightly different, the mentioned causes and their frequencies basically match the results of actual studies [22–28]. In an analysis of 460 revisions after ACL reconstruction, Wright et al. [22] describe the trauma-induced rupture (22–55 %) followed by operation-technical causes (24–53 %) especially including incorrect positioning of drilling tunnels as the main reason for graft failure. The results of this study only mirror the subjective opinion of the surgeons participating in the survey about the general frequency respectively the frequency among their own patients without embodying a valid data collection. Although low-volume-surgeons estimate the frequency of graft failure to be slightly higher, the answers to the survey essentially match the actual revision rates [23, 29, 30].

Compared to the references in literature concerning frequency of infections after ACL reconstruction (1–5 % [31–33]), the frequency among the surgeon's own patient population (0.8 %) is estimated to be lower than the general infection rate (2.1 %) by both high- and low-volume-surgeons. However, estimates about the general infection frequency basically match the reference's statistics.

The outcome of the study suggests in a consensus that the treatment of infections after ACL reconstructions contains antibiotics and multiple irrigations of the knee. Differences exist regarding the duration of antibiotic treatment. 75 % of the respondents prefer a treatment for 4–6 weeks (6 weeks 45 %, 4 weeks 30 %). Short-term antibiosis lasting 2 weeks is implemented in 17 % of the cases and long-term antibiosis in 6 %.

Throughout the present study, several restrictions underlie. The relatively low response rate of 22 % constitutes a certain bias. As ACL reconstructions are not implemented in every orthopedic and surgical clinic, the response rate is partially explainable taking into consideration that most certainly these clinics have a lack of interest to respond. The problem of different interests carries the risk that participating departments do not mirror the actually practiced status quo of ACL rupture treatment in Germany. High shares of clinics with a low quantity of annual operations and low operation rates per surgeon indicate that a relatively wide cross section of clinics was converted to answer the questionnaire. Hence, the previous fact argues for the validity of the results.

Moreover, the definition of specialized subgroups can be discussed critically. Universally accepted definitions do not exist. Therefore, common and already published criteria like the frequency of implemented operations per surgeon and the membership in professional associations were applied. Ultimately, only subjective assessments were questioned throughout the survey mirroring the status quo of the diagnostics and treatments of ACL ruptures in Germany.

Compliance with ethical standards

Conflict of interest None.

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