



Prevailing disagreement in the treatment of complex patellar instability cases: an online expert survey of the AGA Knee–Patellofemoral Committee

A. Geierlehner¹ · M. Liebensteiner² · P. Schöttle³ · F. Dirisamer⁴

Received: 10 June 2019 / Accepted: 28 February 2020 / Published online: 17 March 2020
© European Society of Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA) 2020

Abstract

Purpose To evaluate the current state of knowledge and potential controversies in the treatment of patellofemoral instability among orthopaedic/trauma surgeons in the German-speaking countries.

Methods An online survey consisting of 32 questions and three fictitious cases was sent to members of the AGA—Society for Arthroscopy and Joint Surgery. Surgeons were defined by our senior authors as high-volume or low-volume surgeons, depending on the number of their cases. The treatment of 25% of patients with patellofemoral instability and/or the performance of 50 patellofemoral instability cases per year distinguishes high- from low-volume surgeons in this study.

Results The online questionnaire was completed by 541 experienced knee surgeons from Germany (78%), Austria (10.9%), Switzerland (10.4%) and other countries (0.7%). Most surgeons prefer MPFL reconstruction as surgical intervention in patients with recurrent patellar instability (64–81%). Sixty percent of high-volume surgeons as compared to 21.8% of low-volume surgeons have ever performed a trochleoplasty. Of the overall respondents, 25% would not perform any surgical treatment on adolescents with patellar instability and an open growth plate. Of all responding surgeons, 95% would not treat patellofemoral instability with an isolated lateral release. This corresponds to recent literature showing poor outcome of its strictly isolated application.

Conclusion This study provides an overview of the current management of acute and recurrent patellofemoral instability in the German-speaking countries. Results show the surgeons' awareness for highly demanding surgical possibilities for complex patellar instability cases. However, disagreement among surgeons still prevails when it comes to selecting individual multimodal treatment options. This highlights the need for treatment guidelines and algorithms for patellofemoral instability.

Level of evidence V.

Keywords Patellofemoral instability · Patellar dislocation · Knee surgery · Patella · Surgical treatment

Introduction

Patellar instability is a discontinuity of patellar gliding during knee flexion and/or extension usually caused by a combination of abnormal bony restraints and dysfunction of active and passive soft tissue [15, 29]. Approximately, 7 per 100,000 people suffer from acute patellar dislocation each year, accounting for up to 3% of all knee injuries [3, 47]. The most commonly affected group are female adolescents with 33 per 100,000 cases annually [3]. An indirect mechanism during sports activities without any external trauma seems to be the major contributor to first-time acute patellar dislocation [3, 44]. Up to 50% of patients with first-time patellar dislocation develop various sequelae such as anterior knee pain, osteochondral injuries and degenerative changes [9,

✉ A. Geierlehner
alexander@geierlehner.com

¹ Medical University of Vienna, Spitalgasse 23, 1090 Vienna, Austria

² Department of Orthopaedic Surgery, Medical University of Innsbruck, Innsbruck, Austria

³ Knee and Health Institute Munich GbR, Frauenplatz 7, 80331 Munich, Germany

⁴ Orthopädie und Sportchirurgie Dr. Dirisamer/Dr. Patsch, Schloss Puchenu, Karl-Leitl-Str. 1, 4048 Linz-Puchenu, Austria

21, 28, 43]. Of patients with first-time patellar dislocation 17%, and almost 50% of patients with a history of recurrent patellar dislocations, experienced further episodes of patellar instability [17].

For the last few decades, various non-surgical methods have been considered the treatment of choice in the management of acute patellar dislocation without osteochondral fractures [8]. Recurrent lateral patellar dislocation is nowadays known to be a multifactorial issue, including limb malalignment, pathological bony structures and an imbalance of static and/or dynamic constraints [53]. Non-operative treatment regimens usually fail to address all anatomic and alignment-related factors concomitantly, subsequently leading to a higher failure rate in patients with more complex patellofemoral instability [1]. Patients with more complex acute and especially patients with recurrent patellar dislocations therefore require surgical intervention [53]. In the last few decades, numerous surgical approaches have been developed and modified in an attempt to address the underlying cause of patellar dislocations [1, 18, 38]. A detailed look at those surgical procedures lies beyond the scope of this study. The lack of a clear consensus and guidelines for the treatment of patellofemoral instability makes it difficult for surgeons to choose the best, adequate treatment for each patient. This study was designed to assess the hypothesis that the treatment of patellofemoral instability remains contradictory among surgeons, especially when it comes to the selection of multimodal treatment strategies or the treatment of adolescents. The aim of this study was to assess the current level of knowledge among orthopaedic and/or trauma surgeons in the German-speaking countries. Treatment habits should be improved and potential controversies be pointed out, depending on the level of experience in the treatment of patellofemoral instability.

Materials and methods

Survey information

An online survey was developed using the AGA—Society for Arthroscopy and Joint Surgery survey tool (powered by SurveyMonkey). The questionnaire is based on a previous study conducted by the International Patellofemoral Study Group [27]. Minor changes were made in the questionnaire including translating it into German prior to its distribution. It was then distributed via email by an authorised AGA member using the AGA database. This database contains all full members of the AGA Society who are registered in the German-speaking countries (Germany, Austria, Switzerland and Liechtenstein). A full AGA member is defined as a fully trained, board-certified trauma and/or orthopaedic surgeon. The questionnaire was accessible

online for 4 weeks in total and was answered anonymously. The questionnaire was sent to 3590 AGA members, all living and practising across the aforementioned German-speaking countries: 813 surgeons responded and contributed to the survey, 541 (66.6%) of whom completed the entire survey. Only surgeons who completed the study were included in further statistical analyses. Of the included surgeons, 422 (78%) practised in Germany, 59 (10.9%) in Austria, 56 (10.4%) in Switzerland and 4 (0.7%) in other German-speaking countries at the time of the survey (Fig. 1). Of the included surgeons, 51% worked solely in a hospital- or academic-based setting, 21.5% in a private-based setting and 27.8% in both hospital- and private-based setting. Of the included surgeons, 58% had more than 15 years of surgical experience.

The survey consisted of 32 questions (single/multiple choice and ranked questions) and three fictitious cases on the subject of patellofemoral instability including closed (single/multiple choice) and open questions as well as questions in ordinal ranking based on the order of priority. The following three main topics were covered in the questionnaire:

- Diagnostics for patellofemoral instability.
- Treatment of patellofemoral instability.
- Patellofemoral instability in children and adolescents.

The purpose of this questionnaire was to evaluate the current knowledge and the preferred treatment methods of orthopaedic and trauma surgeons in the German-speaking countries with increasing case complexity. Surgeons were additionally divided into two groups (high- and low-volume surgeons) according to their experience and expertise in the treatment of patellofemoral instability. This was assessed with the following two questions:

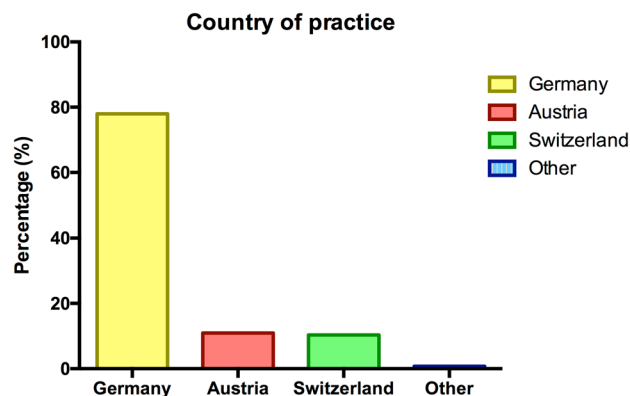


Fig. 1 Percentage of surgeons practising in each German-speaking country

Question 1 “How many patients with patellofemoral instability do you treat per year (in percent of all your patients)?”

Question 2 “How many cases of patellofemoral instability do you treat surgically per year?”

High-volume surgeons were defined as surgeons treating over 25% of their patients for patellofemoral instability and/or performing over 50 patellofemoral instability cases per year. Low-volume surgeons are surgeons treating less than 25% of their patients for patellofemoral instability and/or performing fewer than 50 cases of patellofemoral instability per year. This should provide information on the treatment habits of low- and high-volume surgeons and show whether the level of knowledge in terms of patellofemoral instability diagnostics and treatment is linked to the level of experience. Of the surgeons, 55 (10.2%) treated over 25% of their patients for patellofemoral instability and/or had more than 50 patellofemoral instability cases per year. These 55 surgeons were classified as “high-volume surgeons”, whereas the remaining 486 participants were defined as “low-volume surgeons”.

Statistical analysis

Descriptive statistics and bar charts were used to report demographic data and to illustrate the respondents’ responses. Sample size and power calculation were not performed, since sample size was equivalent to the number of AGA members and this was an analysis of all respondents. Chi-squared and Fisher’s exact tests were used for specific questions to assess whether knowledge and treatment habits correlate with the surgeons’ expertise when comparing high- and low-volume surgeons. Statistical significance was determined as $p < 0.05$. Statistical analyses were performed using SPSS (IBM) and GraphPad Prism (Graphpad Software, Inc.).

Results

Cases

The first fictitious case was a 27-year-old female patient with a first-time traumatic patellar dislocation, Beighton Score 0, normal range of motion (ROM) of the knee, positive apprehension test, patella glide 4 out of 4, a Caton–Deschamps Index 1 and no signs of fractures but a minimal patella subluxation in the radiograph. Of the surgeons, 96% would additionally prefer to have magnetic resonance imaging (MRI) of the knee. The knee MRI did not show any osteochondral fractures or any intra-articular loose bodies. A TT–TG distance of 15.2 mm was calculated and a Dejour type A

trochlea identified. Of the surgeons 447 (82.5%) would not perform any surgery, but would instead use alternative non-surgical methods. In the case of a 12-year-old patient with similar pathologies and an open growth plate, 490 (90%) surgeons would not perform any surgical procedure. However, if the MRI showed an osteochondral fracture in the above-mentioned 27-year-old female patient, about 90% of the surgeons would perform surgery to treat the patellar instability and the osteochondral fracture at the same time.

Case 2 is a 20-year-old female patient with a history of three patellar dislocations suffered during sports activities, no previous knee surgeries and a normal bony anatomy (Caton–Deschamps Index 1.1, TT–TG distance 11 mm, Dejour type A trochlea), except for a fixed lateral patellar tilt. Of the respondents, 507 (> 90%) would treat this patient surgically, and 48% of these surgeons would employ a combination of multiple surgical procedures. Of the 507 surgeons, 81% recommended reconstruction of the medial patellofemoral ligament (MPFL) or the medial quadriceps tendon-femoral ligament (MQTFL) (Fig. 2), 49% without any additional surgical procedure and 51% as a multimodal approach. Of the respondents, 8% would perform bony procedures, such as antero- and medialisation tibial tubercle osteotomy, in addition to reconstruction of medial ligaments, and 3.5% would perform solely bony procedures without any additional surgery of the soft tissue. Of the surgeons who recommended a lateral release, 100% would perform it only as an adjunct to other surgical procedures in this case.

Case 3 is a 20-year-old female patient presenting with a recurrent third-time atraumatic patellar dislocation. Medical imaging of the knee showed abnormal bony anatomy with a Caton–Deschamps Index of 1.4, TT–TG distance 22 mm and a Dejour type B trochlea. Similar to the previous case, more than 90% of the respondents would perform surgery. Of those surgeons, 66% recommended a multimodal surgical approach, as shown in Fig. 3. However, in this case only 64.5% of respondents would perform an MPFL or MQTFL reconstruction, 75% of them as a combination with other surgical procedures and 25% as an isolated MPFL/MQTFL reconstruction. Medialisation osteotomy of the tibial tuberosity was the preferred bony procedure in Case 3, recommended by 55% of the respondents (83% combined with soft tissue or other bony procedures and 17% as a single surgical intervention). Of the respondents, 100% would not perform a lateral release of the soft tissue without an additional surgical procedure.

High- vs. low-volume surgeons

This chapter compares the responses received from high-volume and low-volume surgeons. Of the high-volume surgeons, 51% and 67% would perform more than one surgical procedure in the above-mentioned Case 2 and Case 3,

Fig. 2 Surgical treatment recommendations for Case 2 (multiple answers possible)

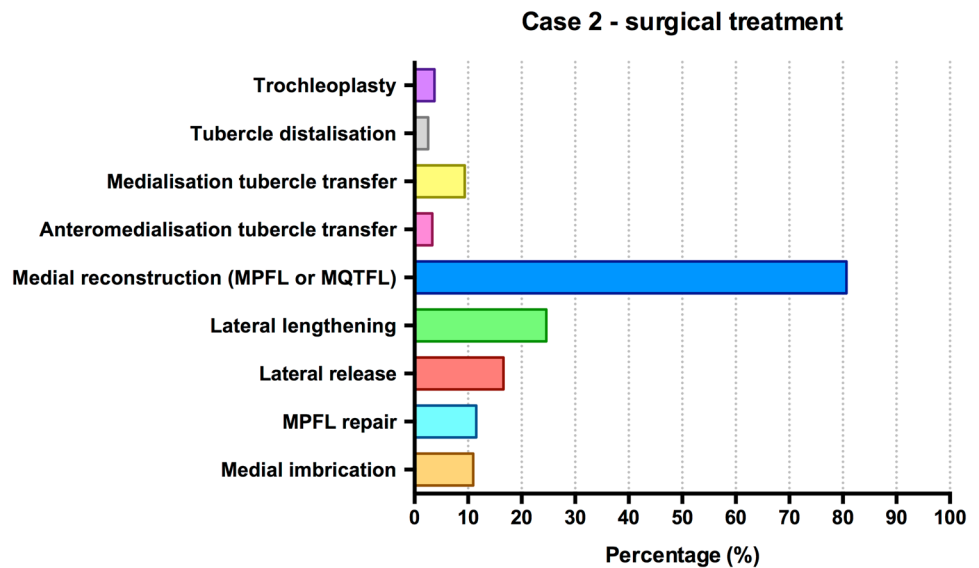
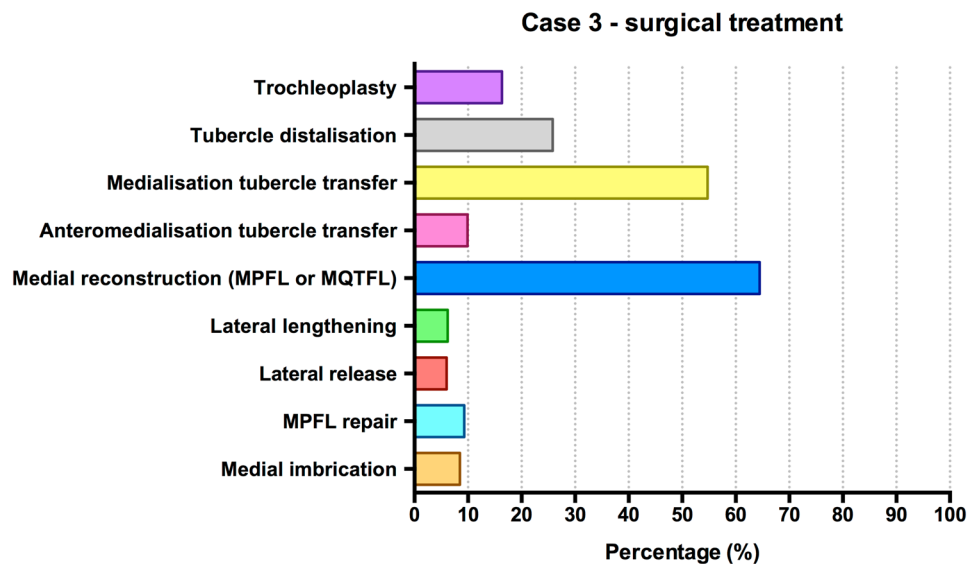


Fig. 3 Surgical treatment recommendations for Case 3 (multiple answers possible)



respectively. Contrarily, 49% and 66% of the low-volume surgeons would combine at least two surgical procedures in Case 2 and Case 3, respectively. The proportion of surgeons recommending a multimodal treatment approach, irrespective of the exact combination of surgeries, did not significantly differ between the high- and low-volume surgeons in either case (Case 2: p value: n.s.; Case 3: p value: n.s.) as shown in Fig. 4a and b.

In Case 3, 9% of the high-volume and 1% of the low-volume surgeons additionally recommended preoperative analysis of potential knee deformities to assess whether a more challenging knee osteotomy might be indicated or not. This results in a significant difference between high- and low-volume surgeons, indicating that more surgical

experience tends to correlate with the use of further, more sophisticated preoperative analysis.

Of the respondents, 406 (79%) (87% of the high-volume surgeons and 78% of the low-volume surgeons) believe trochleoplasty can play a role in the treatment of recurrent patellar dislocations. No significant difference between high- and low-volume surgeons regarding the indication for trochleoplasty for recurrent patellar dislocations was detected (p value: n.s.) (Fig. 5).

However, only 139 (26%) of the respondents, namely 60% of the high-volume surgeons and 21.8% of the low-volume surgeons, have ever performed a trochleoplasty. A Chi-squared test showed that the high-volume surgeons have significantly more experience with the trochleoplasty

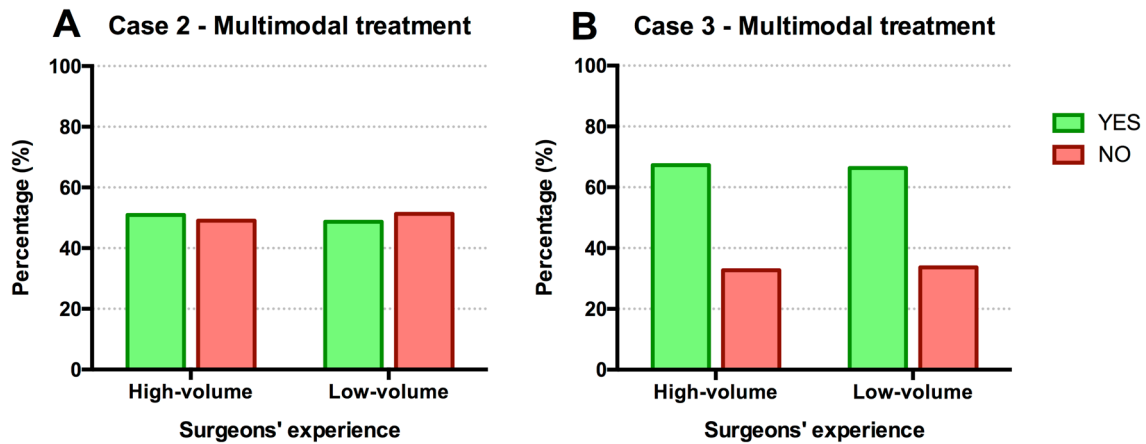


Fig. 4 a Case 2 multimodal treatment approach (YES or NO) high- vs. low-volume surgeons; b Case 3 multimodal treatment approach (YES or NO) high- vs. low-volume surgeons

Trochleoplasty for recurrent patellar dislocation

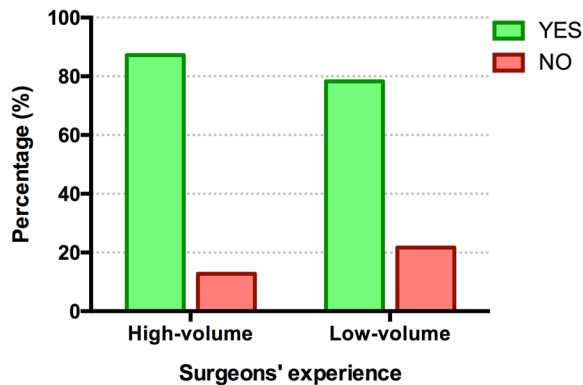


Fig. 5 “Can trochleoplasty play a role in patients with recurrent patellar dislocation?” (yes or no). Comparison of high- vs. low-volume surgeons

Have you ever performed a trochleoplasty?

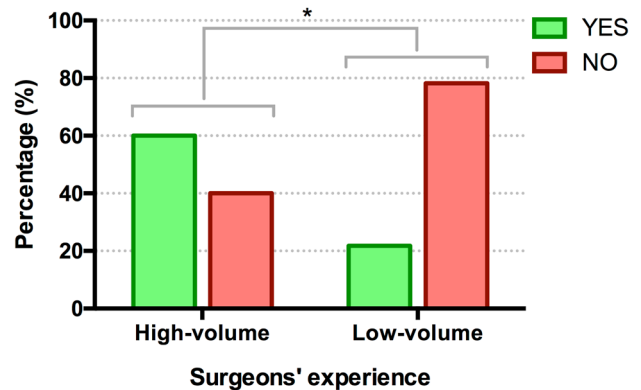


Fig. 6 “Have you ever performed a trochleoplasty?” (yes or no). Comparison of high- vs. low-volume surgeons. *Indicates statistically significant difference

procedures than do the low-volume surgeons ($p < 0.0001$) (Fig. 6).

Derotational osteotomy

Of the respondents, 73% would perform derotational osteotomy to treat recurrent patellar dislocations at different degrees of femoral antetorsion, 27% would consider such a procedure only with $> 30^\circ$ femoral antetorsion, 16% with $> 25^\circ$, 23% with $> 20^\circ$ and 5% of the respondents with $> 15^\circ$ femoral antetorsion. Only a small part of the respondents (2%) would already consider femoral osteotomy with $< 15^\circ$ femoral antetorsion, whereas 27% would not perform derotational osteotomy for the treatment of patellofemoral instability at all (Fig. 7). A Fisher’s exact test showed that a significantly higher percentage of the

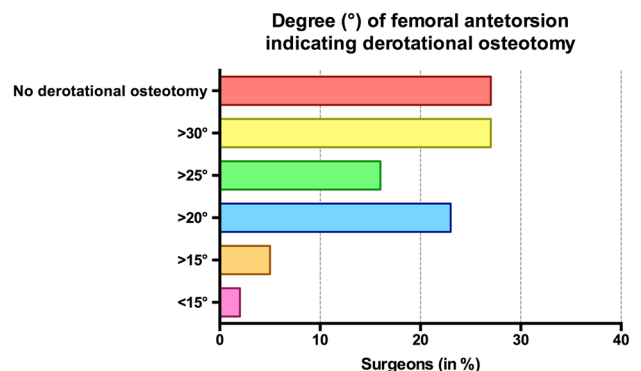


Fig. 7 Minimum degree of femoral antetorsion, which indicates derotational osteotomy in patients with recurrent patellar dislocation and failed proximal and distal knee realignment procedures

low-volume surgeons (29% of the low-volume respondents) as compared to 8% of the high-volume surgeons refused to perform derotational osteotomies ($p < 0.0007$).

Adolescent patellofemoral instability

Of the respondents, 25% would perform patellofemoral surgery only on adolescents with an entirely closed growth plate. However, about 60% of the surgeons would consider guided growth methods (e.g. hemiepiphysiodesis) in patients with valgus knees, open growth plates and recurrent patellar instability. Half of these 60% would concomitantly surgically address other possible causes of patellofemoral instability.

Lateral release

Of the respondents, 95% would not perform any lateral release of the soft tissue as a single procedure for the treatment of patellar instability.

Discussion

The most important finding of the present study was that complex patellofemoral cases still lack clear treatment guidelines. The outcome of such cases seems to be dependent on the experience of the treating physician and his or her volume of complex patellofemoral instability cases. This study shows that the ability to perform challenging procedures with significant biomechanical consequences for the patellofemoral joint such as trochleoplasty or derotational osteotomy is mostly limited to highly experienced surgeons. Other than a few research groups proposing their treatment algorithm [14, 26, 53] and consensus statements [27, 37], the literature still lacks standard treatment guidelines for patellofemoral instability. This study should improve our understanding of current treatment habits and point out potential controversies among orthopaedic and trauma surgeons in the German-speaking countries.

In the case of a first-time patellar dislocation with low risk of developing recurrent patellar dislocation [4], most surgeons prefer non-operative management. However, the majority additionally require MRI diagnostics to rule out potential osteochondral fractures or a disruption of the medial soft tissue stabilisers. The literature on acute patellar dislocation treatment remains contradictory. Prospective studies comparing mid- and long-term outcomes of surgical and conservative treatment in patients with acute patellar dislocation could not detect a benefit for either treatment arm [34, 45]. On the contrary, a recently conducted systematic review and meta-analysis showed surgical intervention to have possible advantages in terms of re-dislocation risk and return to activity [46]. Current literature suggests

non-surgical treatment of acute patellar dislocation only if no osteochondral fractures or signs of MPFL disruption prevail [47]. The Patellar Instability Severity Score (PIS Score) [4] and predefined risk factors of patellar dislocation [23] permit patients to be identified who are at risk for suffering further patella dislocation events. In the case of additional osteochondral fractures, 90% of the included surgeons recommended surgery in patients with acute patellar dislocation. The majority of the included surgeons also favoured surgery in patients suffering from recurrent patellar dislocation. Given the fact that MPFL reconstruction has shown good clinical outcome according to a meta-analysis by Schneider et al. [40], it is not surprising that most surgeons preferred MPFL reconstruction, either as a single procedure or in combination with other soft tissue or bony procedures. An increase in case complexity (from Case 2 to Case 3) led to an increase in multimodal treatment recommendations. Most surgeons included in this survey would not perform any surgery on adolescents with first-time dislocation and open physes. This is in accordance with recommendations recently made in the literature [2]. Surgical options for skeletally immature patients are guided growth in the case of genu valgum, distal realignment and MPFL reconstruction [20]. Although MPFL reconstruction in children and adolescents with recurrent dislocations showed promising results [32], 25% of the respondents in this study still considered surgery only as an appropriate intervention in skeletally mature patients with an entirely closed growth plate.

Trochleoplasty is a well-established surgical method that aims to reconstruct the physiological anatomy of the trochlear groove, subsequently enabling patellar stability and patellar glide during knee flexion [6]. Many different trochleoplasty techniques have been published in support of their effectiveness for the treatment of recurrent patellar dislocations with high-grade trochlea dysplasia [5, 7, 10, 13, 31, 33, 35, 39, 42, 49–51]. Most surgeons in this study (79%) as well as in the study by Liu et al. (80%) seem to be aware of the important role of trochleoplasty procedures in recurrent patellar dislocation [27]. Only 25% of the overall respondents, but 60% of the high-volume surgeons in this study have ever performed a trochleoplasty. By comparison, almost 80% of the absolute experts included in the study by Liu et al. had experience with trochleoplasty procedures [27]. Results show that trochleoplasty is considered a highly challenging surgical procedure that is mainly performed by experienced surgeons with large case numbers.

Derotational osteotomy is another surgical method strongly discussed in recent literature. Various authors have published derotational osteotomy case series with mean femoral torsion angles from 34° to 41° [11, 12, 31]. Standard values for femoral torsion are required to define a pathological femur torsion threshold that indicates derotational osteotomy. However, norm values published in recent studies

vary as a result of different measurement techniques used [24]. After comparing different measurement techniques, Kaiser et al. [24] recommend the technique described by Waidelich et al. [52] with mean physiological torsion angles between 20.4° and 24.1° [48, 52]. Recent studies considered derotational osteotomies in patients with symptomatic patellar dislocation and femoral antetorsion angles greater than 20° [22, 30, 31]. This corresponds to the results of this questionnaire. Only 7% of the respondents in this survey would already perform derotational osteotomy in patients with less than 20° femoral antetorsion. A significant percentage (27%) of the included surgeons as compared to 34% in the study by Liu et al. would not perform derotational osteotomy despite promising results recently published by several research groups [11, 12, 22, 27, 31]. Overall, the results show that this surgical technique still seems to be the subject of controversy among surgeons.

Historically, isolated lateral retinacular release has been used for the treatment of patellofemoral instability [41]. Studies assessing long-term outcomes showed an increased risk for various sequelae such as hemarthrosis, adhesions and medial patellar instability [25, 36]. This led to the abandonment of strictly isolated lateral release for the treatment of patellar instability. Favourably modified as lateral retinacular lengthening, it should be used only as an adjunct to proximal or distal realignment procedures [25] or in patients with excessive lateral pressure syndrome [16, 19]. Of the surgeons in this study, 95% seem to be aware of its restricted use, similar to those surgeons included in the survey by Liu et al. [27]

Demographics of this survey show that only 813 surgeons out of 3,590 full AGA members responded and only 541 surgeons completed the entire questionnaire. The high dropout rate (85%) introduces the possibility of participation bias. However, the dropout rate was not unexpected or surprising for the authors, since the survey was directed at absolute knee specialists among the AGA members. The demographics of this study also shows an unbalanced proportion between high- and low-volume surgeons. However, this was expected by the authors since it reflects clinical practice. Some study participants criticised the design of the questionnaire with its lack of clinical information and medical imaging provided. The authors were aware of the limited scope of patient information in the three fictitious cases. However, to enable comparison with the original questionnaire designed by Liu et al. [27], it was necessary to keep the main body of the questionnaire in its original state. This work may improve our understanding of the complexity of patellofemoral instability and thus sharpen the focus of physicians on all pathological details with significant influence on the patellofemoral joint. It should help to identify complex patellofemoral instability cases in the day by day clinical work which should be transferred to a certified centre

with highly experienced surgeons. This will improve the overall outcome of complex cases and avoid revision cases due to pain or recurrent instabilities.

Conclusion

This study gives an overview of the current treatment habits for acute and recurrent patellofemoral instability in the German-speaking countries. Results show that an awareness for highly demanding surgical possibilities exists among these surgeons. However, disagreement still prevails when it comes to selecting individual surgical treatment, especially with an increase in case complexity. This highlights the need for standard treatment guidelines and algorithms for patellofemoral instability.

Acknowledgements The authors specially thank the entire AGA Knee–Patellofemoral Committee (in particular: Priv.-Doz. Dr. med. Peter Balcarek, Prof. Dr. med. Christoph Becher, Priv.-Doz. Dr. med. René El Attal, PD Dr. med. univ. Armin Keshmiri, Priv.-Doz. Dr. med. Geert Pagenstert, Dr. med. Gerd Seitlinger, Dr. med. Daniel Wagner) for supporting this study. The authors hereby also want to thank all AGA-members who participated in this survey. A special gratitude goes out to Ms. Eva-Maria Pinz who managed the online distribution of the questionnaire.

Compliance with ethical standards

Conflict of interest Prof. Dr. Med. Philip Schöttle declares having royalty agreements with Arthrex, Inc. and Arthrosurface. Prof. Dr. Med. Philip Schöttle and Dr. Dirisamer act as consultants for Arthrex Inc. All other authors declare having no conflict of interest.

Funding No funding was directly received for the development of this manuscript.

Ethical approval The study was approved by the Ethics Committee of the Medical University of Vienna, Austria.

References

1. Alaia MJ, Cohn RM, Strauss EJ (2014) Patellar instability. *Bull Hosp Jt Dis* 72:6–17
2. Antinolfi P, Bartoli M, Placella G, Speziali A, Pace V, Delcogliano M, Mazzola C (2016) Acute patellofemoral instability in children and adolescents. *Joints* 4:47–51
3. Atkin DM, Fithian DC, Marangi KS, Stone ML, Dobson BE, Mendelsohn C (2000) Characteristics of patients with primary acute lateral patellar dislocation and their recovery within the first 6 months of injury. *Am J Sports Med* 28:472–479
4. Balcarek P, Oberthur S, Hopfensitz S, Frosch S, Walde TA, Wachowski MM, Schuttrumpf JP, Sturmer KM (2014) Which patellae are likely to redislocate? *Knee Surg Sports Traumatol Arthrosc* 22:2308–2314
5. Banke IJ, Kohn LM, Meidinger G, Otto A, Hensler D, Beitzel K, Imhoff AB, Schöttle PB (2014) Combined trochleoplasty and MPFL reconstruction for treatment of chronic patellofemoral

- instability: a prospective minimum 2-year follow-up study. *Knee Surg Sports Traumatol Arthrosc* 22:2591–2598
6. Beaufils P, Thaunat M, Pujol N, Scheffler S, Rossi R, Carmont M (2012) Trochleoplasty in major trochlear dysplasia: current concepts. *Sports Med Arthrosc Rehabil Ther Technol* 4:7
 7. Blond L, Haugegaard M (2014) Combined arthroscopic deepening trochleoplasty and reconstruction of the medial patellofemoral ligament for patients with recurrent patella dislocation and trochlear dysplasia. *Knee Surg Sports Traumatol Arthrosc* 22:2484–2490
 8. Cash JD, Hughston JC (1988) Treatment of acute patellar dislocation. *Am J Sports Med* 16:244–249
 9. Cofield RH, Bryan RS (1977) Acute dislocation of the patella: results of conservative treatment. *J Trauma* 17:526–531
 10. Dejour D, Byn P, Ntangiopoulos PG (2013) The Lyon's sulcus-deepening trochleoplasty in previous unsuccessful patellofemoral surgery. *Int Orthop* 37:433–439
 11. Dickschas J, Harrer J, Pfefferkorn R, Strecker W (2012) Operative treatment of patellofemoral maltracking with torsional osteotomy. *Arch Orthop Trauma Surg* 132:289–298
 12. Dickschas J, Harrer J, Reuter B, Schwitulla J, Strecker W (2015) Torsional osteotomies of the femur. *J Orthop Res* 33:318–324
 13. Donell ST, Joseph G, Hing CB, Marshall TJ (2006) Modified Dejour trochleoplasty for severe dysplasia: operative technique and early clinical results. *Knee* 13:266–273
 14. Duerr RA, Chauhan A, Frank DA, DeMeo PJ, Akhavan S (2016) An algorithm for diagnosing and treating primary and recurrent patellar instability. *JBJS Rev* 4:9
 15. Elias DA, White LM (2004) Imaging of patellofemoral disorders. *Clin Radiol* 59:543–557
 16. Ficat P (1978) The syndrome of lateral hyperpressure of the patella. *Acta Orthop Belg* 44:65–76
 17. Fithian DC, Paxton EW, Stone ML, Silva P, Davis DK, Elias DA, White LM (2004) Epidemiology and natural history of acute patellar dislocation. *Am J Sports Med* 32:1114–1121
 18. Frosch S, Balcarek P, Walde TA, Schuttrumpf JP, Wachowski MM, Ferleman KG, Sturmer KM, Frosch KH (2011) The treatment of patellar dislocation: a systematic review. *Z Orthop Unfall* 149:630–645
 19. Fulkerson JP (2002) Diagnosis and treatment of patients with patellofemoral pain. *Am J Sports Med* 30:447–456
 20. Gausden EB, Fabricant PD, Taylor SA, McCarthy MM, Weeks KD, Potter H, Shubin Stein B, Green DW (2015) Medial patellofemoral reconstruction in children and adolescents. *JBJS Rev* 3:10
 21. Hawkins RJ, Bell RH, Anisette G (1986) Acute patellar dislocations. The natural history. *Am J Sports Med* 14:117–120
 22. Imhoff FB, Cotic M, Liska F, Dyrna FGE, Beitzel K, Imhoff AB, Herbst E (2019) Derotational osteotomy at the distal femur is effective to treat patients with patellar instability. *Knee Surg Sports Traumatol Arthrosc* 27:652
 23. Jaquith BP, Parikh SN (2017) Predictors of recurrent patellar instability in children and adolescents after first-time dislocation. *J Pediatr Orthop* 37:484–490
 24. Kaiser P, Attal R, Kammerer M, Thauerer M, Hamberger L, Mayr R, Schmoelz W (2016) Significant differences in femoral torsion values depending on the CT measurement technique. *Arch Orthop Trauma Surg* 136:1259–1264
 25. Lattermann C, Toth J, Bach BR Jr (2007) The role of lateral retinacular release in the treatment of patellar instability. *Sports Med Arthrosc Rev* 15:57–60
 26. Liebensteiner MC, Dirisamer F, Balcarek P, Schoettle P (2017) Guidelines for treatment of lateral patella dislocations in skeletally mature patients. *Am J Orthop* 46:E86–E96
 27. Liu JN, Steinhaus ME, Kalbian IL, Post WR, Green DW, Strickland SM, Shubin Stein BE (2017) Patellar instability management: a survey of the international patellofemoral study group. *Am J Sports Med* 46:3299–3306
 28. Maenpaa H, Lehto MU (1997) Patellofemoral osteoarthritis after patellar dislocation. *Clin Orthop Relat Res* 339:156–162
 29. McConnell J (2007) Rehabilitation and nonoperative treatment of patellar instability. *Sports Med Arthrosc Rev* 15:95–104
 30. Nelitz M (2018) Femoral derotational osteotomies. *Curr Rev Musculoskelet Med* 11:272–279
 31. Nelitz M, Dreyhaupt J, Lippacher S (2013) Combined trochleoplasty and medial patellofemoral ligament reconstruction for recurrent patellar dislocations in severe trochlear dysplasia: a minimum 2-year follow-up study. *Am J Sports Med* 41:1005–1012
 32. Nelitz M, Dreyhaupt J, Reichel H, Woelfle J, Lippacher S (2013) Anatomic reconstruction of the medial patellofemoral ligament in children and adolescents with open growth plates: surgical technique and clinical outcome. *Am J Sports Med* 41:58–63
 33. Neumann MV, Stalder M, Schuster AJ (2016) Reconstructive surgery for patellofemoral joint incongruity. *Knee Surg Sports Traumatol Arthrosc* 24:873–878
 34. Nikku R, Nietosvaara Y, Aalto K, Kallio PE (2005) Operative treatment of primary patellar dislocation does not improve medium-term outcome: a 7-year follow-up report and risk analysis of 127 randomized patients. *Acta Orthop* 76:699–704
 35. Ntangiopoulos PG, Byn P, Dejour D (2013) Midterm results of comprehensive surgical reconstruction including sulcus-deepening trochleoplasty in recurrent patellar dislocations with high-grade trochlear dysplasia. *Am J Sports Med* 41:998–1004
 36. Panni AS, Tartarone M, Patricola A, Paxton EW, Fithian DC (2005) Long-term results of lateral retinacular release. *Arthroscopy* 21:526–531
 37. Post WR, Fithian DC (2018) Patellofemoral instability: a consensus statement from the aossm/pff patellofemoral instability workshop. *Orthop J Sports Med* 6:2325967117750352
 38. Redziniak DE, Diduch DR, Mihalko WM, Fulkerson JP, Novicoff WM, Sheibani-Rad S, Saleh KJ (2009) Patellar instability. *J Bone Joint Surg Am* 91:2264–2275
 39. Rouanet T, Gougeon F, Fayard JM, Remy F, Migaud H, Pasquier G (2015) Sulcus deepening trochleoplasty for patellofemoral instability: a series of 34 cases after 15 years postoperative follow-up. *Orthop Traumatol Surg Res* 101:443–447
 40. Schneider DK, Grawe B, Magnussen RA, Ceasar A, Parikh SN, Wall EJ, Colosimo AJ, Kaeding CC, Myer GD (2016) Outcomes after isolated medial patellofemoral ligament reconstruction for the treatment of recurrent lateral patellar dislocations: a systematic review and meta-analysis. *Am J Sports Med* 44:2993–3005
 41. Schonholtz GJ, Zahn MG, Magee CM (1987) Lateral retinacular release of the patella. *Arthroscopy* 3:269–272
 42. Schottle PB, Fucentese SF, Pfirrmann C, Bereiter H, Romero J (2005) Trochleoplasty for patellar instability due to trochlear dysplasia: a minimum 2-year clinical and radiological follow-up of 19 knees. *Acta Orthop* 76:693–698
 43. Seeley MA, Knesek M, Vanderhave KL (2013) Osteochondral injury after acute patellar dislocation in children and adolescents. *J Pediatr Orthop* 33:511–518
 44. Sillanpaa P, Mattila VM, Iivonen T, Visuri T, Pihlajamaki H (2008) Incidence and risk factors of acute traumatic primary patellar dislocation. *Med Sci Sports Exerc* 40:606–611
 45. Sillanpaa PJ, Maenpaa HM, Mattila VM, Visuri T, Pihlajamaki H (2008) Arthroscopic surgery for primary traumatic patellar dislocation: a prospective, nonrandomized study comparing patients treated with and without acute arthroscopic stabilization with a median 7-year follow-up. *Am J Sports Med* 36:2301–2309
 46. Smith TO, Song F, Donell ST, Hing CB (2011) Operative versus non-operative management of patellar dislocation: a meta-analysis. *Knee Surg Sports Traumatol Arthrosc* 19:988–998

47. Stefancin JJ, Parker RD (2007) First-time traumatic patellar dislocation: a systematic review. *Clin Orthop Relat Res* 455:93–101
48. Strecker W, Keppler P, Gebhard F, Kinzl L (1997) Length and torsion of the lower limb. *J Bone Joint Surg Br* 79:1019–1023
49. Thaanat M, Bessiere C, Pujol N, Boisrenoult P, Beaufils P (2011) Recession wedge trochleoplasty as an additional procedure in the surgical treatment of patellar instability with major trochlear dysplasia: early results. *Orthop Traumatol Surg Res* 97:833–845
50. Utting MR, Mulford JS, Eldridge JD (2008) A prospective evaluation of trochleoplasty for the treatment of patellofemoral dislocation and instability. *J Bone Joint Surg Br* 90:180–185
51. von Knoch F, Bohm T, Burgi ML, von Knoch M, Bereiter H (2006) Trochleaplasty for recurrent patellar dislocation in association with trochlear dysplasia. A 4- to 14-year follow-up study. *J Bone Joint Surg Br* 88:1331–1335
52. Waidelich HA, Strecker W, Schneider E (1992) Computed tomographic torsion-angle and length measurement of the lower extremity. The methods, normal values and radiation load. *Rofa* 157:245–251
53. Weber AE, Nathani A, Dines JS, Allen AA, Shubin-Stein BE, Arendt EA, Bedi A (2016) An algorithmic approach to the management of recurrent lateral patellar dislocation. *J Bone Joint Surg Am* 98:417–427

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.