Vilnius University Press

Contents lists available at Vilnius University Press

Lietuvos chirurgija
2023, vol. 22(4), pp. 206–212

ISSN 1392–0995 eISSN 1648–9942
DOI: https://doi.org/10.15388/LietChirur.2023.22(4).1

Surgical treatment of Hallux Rigidus – arthrodesis or resection arthroplasty? Retrospective observational study

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Abstract. Introduction. Hallux Rigidus, a degenerative disease of the first metatarsophalangeal joint (MTP), causes pain during movement, reduces joint mobility, and impairs quality of life. Conservative treatment methods are effective only in the early stages of the disease, and surgical treatment is usually recommended for advanced pathology. Arthrodesis procedure is the gold standard. This surgery effectively and relatively quickly reduces painful symptoms but sacrifices joint mobility. An alternative is resection arthroplasty. There is no consensus in the literature regarding the long-term outcomes of these two treatment methods. The aim of this study is to determine which method is superior in improving patients' quality of life and foot function. *Methods.* A retrospective observational study was conducted on 41 patients who were followed up for 2–4 years after surgery. Of these, 20 underwent resection arthroplasty, 21 – arthrodesis. Patients' quality of life and subjective foot function were assessed using two standardized questionnaires: SEFAS and Short Form-12. Additional questions on patient satisfaction with the surgery were also evaluated. *Results.* Patient satisfaction with the surgery was high in both groups (80%). There were no statistically significant differences in patients' ankle and foot function assessed by SEFAS scale and psychological quality of life assessed by SF 12 (Mental Score): $p = 0.14$ and $p = 0.729$, respectively. Patients rated their physical quality of life significantly better, assessed by SF 12 (Physical Score), after undergoing arthroplasty ($p = 0.02$), and foot function recovered approximately 1 month faster compared to arthrodesis ($p = 0.006$). There were no cases of revision surgery, infectious complications, or non-unions in either group. *Conclusions.* Both surgical techniques are effective and improve patients' functional status, but subjective foot function is better in the early postoperative period after resection arthroplasty. The majority of patients in both groups would recommend the surgery under similar circumstances.

Keywords: Hallux rigidus, arthrodesis, resection arthroplasty, interposition arthroplasty, first metatarsophalangeal joint.

Received: 2023/04/25. **Accepted:** 2023/07/01.

Chirurginis *Hallux algus* gydymas: artrodezė ar rezekcinė artroplastika? Retrospektyvinė stebėsenos studija

Santrauka. *Įvadas.* Kojos nykščio metatarsofalanginio sąnario degeneracinė liga (*Hallux rigidus*) sukelia skausmą judesio metu, mažina sąnario judrumą ir blogina gyvenimo kokybę. Gydant pažengusią I MTP sąnario artrozę, vadinamuoju auksiniu gydymo standartu laikytina artrodezė. Ši operacija efektyviai ir pakankamai greitai sumažina skausmo simptomus, tačiau paaukojamas sąnario mobilumas. Alternatyva – rezekcinė artroplastika. Mokslinėje literatūroje, lyginant abiejų gydymo metodų tolimuosius rezultatus, nuomonės išsiskiria. Šio tyrimo tikslas – išsiaiškinti, kuris metodas yra pranašesnis, gerinant pacientų gyvenimo kokybę ir pėdos funkcinę būklę. *Metodai.* Atlikta retrospektyvi stebimoji studija, į tiriamąją imtį įtraukiant 41 pacientą, praėjus 2–4 metams po operacijos. 20 tiriamųjų buvo atlikta rezekcinė artroplastika, 21 pacientui – artrodezė. Pacientų gyvenimo kokybė ir subjektyvi pėdos funkcinė būklė vertinta taikant du standartizuotus klausimynus: SEFAS ir *Short Form-12*. Papildomai vertintas bendrasis pacientų pasitenkinimas operacija (atsakymai į klausimus). *Rezultatai.* Abiejose tiriamųjų grupėse pacientų pasitenkinimas atlikta operacija buvo pakankamai aukštas (80 %). Pacientų čiurnos ir pėdos funkcinė būklė, vertinant SEFAS skale, ir psichologinė gyvenimo kokybė, vertinant SF 12 (*Mental Score*) skale, statistiškai reikšmingai nesiskyrė (atitinkamai p = 0,14 ir p = 0,729). Pacientai, kuriems buvo atlikta artroplastika, statistiškai reikšmingai geriau vertino fizinę gyvenimo kokybę (vertinta taikant SF 12 (*Physical Score*) skalę; p = 0,02). Minėtina, kad šie pacientai maždaug 1 mėn. greičiau, palyginti su artrodezės rezultatais, susigrąžino pėdos funkciją (p = 0,006). *Išvados.* Abi operacinės metodikos yra veiksmingos ir pagerina pacientų funkcinę būklę, tačiau, atlikus rezekcinę artroplastiką, subjektyvi pėdos funkcinė būklė ankstyvuoju pooperaciniu laikotarpiu buvo geresnė. Didžioji dauguma abiejų tirtų grupių pacientų rekomenduotų atlikti operaciją, esant panašioms aplinkybėms.

Reikšminiai žodžiai: *Hallux rigidus*, artrodezė, rezekcinė artroplastika, interpozicinė artroplastika, pirmasis metakarpalinis sąnarys.

Introduction

Hallux Rigidus (HR) is a degenerative disease of the first foot toe metatarsophalangeal (I MTP) joint. It is one of the most common foot joint pathologies, usually found in older population, progresses with age and is more common among women [1]. The exact cause is not known, but it is associated more often with previous traumas or undergone operations. In a scientific literature it is referred, that the disease is diagnosed more often alongside with knee osteoarthritis, gout, I toe deformation (Hallux Valgus pathology), seronegative arthropathy, long first metatarsal [2]. End-stage disease results in osteophytes formation which narrows the joint space and decreases the range of motion of the I metatarsal joint, especially, extension. Pain is present during flexion due to *extensor hallucis longus* tendon stretching over the osteophytes [3]. Because of these reasons patients' quality of life significantly worsens – they complain about pain while walking, especially during physical activity, altered gait, toe's immobility.

During HR early stages there are a few available conservative treatments: special orthopaedic footwear, foot joint exercises, anti-inflammatory drug injections. Unfortunately, these methods are only useful on a low grade HR, their effectiveness are limited [4, 5]. The main treatment is surgery. The surgical methods can be divided into joint sparing and joint sacrificing. Despite successful arthroplasty of the large joints, I MTP joint endoprosthesis durability is limited, complications rate is unreasonably high, hence why it is not as popular today. The golden standard for this disease is the arthrodesis (AD), during which damaged joint surfaces are removed and the Ist MTP joint is closed using various metal constructions, most commonly, anatomically contoured locking plates. The alternative is joint sparing surgery – resection arthroplasty (AP). During the procedure excessive bony spurs are removed, the scarred tissue is released, moreover, the joint space can be increased by performing shortening osteotomy of the first metatarsal in moderation. The aim of the surgery – eliminate the cause of the pain and preserve the mobility of the joint.

In literature, there is no consensus on when it is more appropriate to choose AD or AP for patients with advanced HR pathology. If done technically, the AD procedure is known for good results: correct alignment of the first toe, stable and painless first metatarsophalangeal (MTP) joint while unloading the pressure on the heads of the remaining metatarsals, and effective pain reduction, with a relatively low rate of complications and a high rate of successful healing (>90%) [6]. However, joint mobility is sacrificed. In contrast, the main advantages of AP include preserving movement of the first MTP joint, usually without leaving any metalwork, and avoiding the risk of non-healing [7].

There is still not enough data in the literature regarding long-term outcomes of these surgeries and comparing them based on patients' subjective perspectives. Recently, clinical practice has been placing greater emphasis on individualized medicine. In order to evaluate treatment results and use optimal treatment strategies in the future, it is necessary to assess distant treatment outcomes. However, modern patients rarely return for long term follow-up clinical evaluations, so special distance patient surveys (patient-reported outcome measures) have been proposed in scientific literature to assess patient satisfaction with the surgery, any persistent or new complaints, and treatment expectations.

The aim of this study is to determine which of the treatment methods we commonly use in our daily practice is superior in improving patients' quality of life and foot function. The study was conducted by surveying patients and having them complete standardized questionnaires. The results were divided according to specific surgeries and compared with each other.

Methods

The study included 41 patients with clinically significant Hallux Rigidus pathology who underwent surgery between year 2017 and 2020. Of these, 20 patients underwent a resection AP operation and 21 patients underwent the AD operation, all performed by the same surgeon. Patients were diagnosed with moderate or severe HR according to the Coughlin and Shurnas rating system, which is commonly used to assess HR [8] (Table 1), based on patient complaints and radiological changes.

A retrospective observational study was conducted using standardized questionnaires to determine whether one of the two surgical methods significantly improved patients' quality of life and subjective foot function. All patients had to answer three questionnaires, which were read by one researcher, and their responses were marked accordingly. The surveys were translated into Lithuanian, so only Lithuanian-speaking patients were surveyed.

The first questionnaire consisted of general questions about the patient, their opinion about the surgery, and its outcome.

During this study, it was not possible to examine objective patient data, therefore a SEFAS (European Foot and Ankle Society) standardized questionnaire based on patient subjective assessment was chosen. The questionnaire consists of 5 questions and is approved to assess a person's physical health by evaluating ankle and foot function over the past week. The SEFAS questionnaire rates physical health from 0 (worst condition) to 4 (best condition). The results are summed up and an average is calculated. Although only subjective data are used to assess the condition, the reliability of HR pathology is not reduced [9].

Short Form-36 (SF-36) is a scale designed to assess the patient's quality of life. It consists of 36 questions aimed at determining physical and mental well-being over the last month [10, 11]. This scale is used in scientific literature to compare HR surgical outcomes [12]. In our study, patients were asked to complete 3 questionnaires simultaneously, so we decided to use a shorter version of the questionnaire – Short Form 12 (SF-12). This scale is also used to assess the quality of life and is a shorter version of the SF-36. Although the questionnaire consists of only 12 questions, it is reliable enough to assess the quality of life [13]. The last questionnaire for the patients was the 12-Item Short-Form Health Survey (SF-12). SF-12 evaluates the quality of life of patients in physical (Physical Score) and psychological (Mental Score) aspects, using a specific calculator for the questionnaire. The result is presented in points. According to the scale, the average quality of life indicator is 50 points.

Statistical analysis was performed using SPSS 18 (SPSS Inc., Chicago, IL) statistical system. The Shapiro-Wilk test was used to evaluate the distribution of variables according to the normal distribution. Normally distributed data was compared using the Student T-test, assessing means and standard deviations, and categorical variables – using Chi-square and Fisher exact tests. Data that did not meet the normality conditions was compared using the Mann-Whitney U test. The significance level was considered $p < 0.05$.

Results

Out of 41 surveyed patients, 20 underwent arthrodesis (AD) and 21 underwent arthroplasty (AP). In the overall questionnaire, patients were asked if they were satisfied with the surgery. In both groups, satisfaction with the surgery reached 80%. The percentage of patients satisfied with the appearance of their foot was the same in both groups at 75%. Additional symptoms were observed in 9 patients (45%) after AP surgery, the most common being persistent pain (5 patients, 25%). 11 patients (51%) reported additional symptoms after AD surgery. Most frequently reported symptom was MTP joint deformity (7 patients, 33%) (p = 0.529).

The average duration between patients' AP surgery and full foot function recovery was 2.8 months. This period was statistically significantly longer for AD patients, with an average of 3.9 months (p = 0.006). In both groups, majority of the patients would recommend surgery (AP – 95%, AD – 90%).

Comparing both groups according to the SEFAS questionnaire, the scores did not differ significantly: 3.71 points in the AP group and 3.38 points in the AD group (p = 0.14).

After calculating the SF12 Physical Score aspect, it was found that this indicator was significantly higher in the AP patient group compared to patients who underwent AD, with scores of 49.77 and 39.89, respectively (p = 0.02). There was no significant difference between the groups when evaluated by Mental Score, with AP patients averaging 50.27 points and AD patients averaging 49.15 points (p = 0.729).

Table 1.

Grade	Dorsiflexion	Radiographic Findings	Clinical Findings
0	40°–60°	Normal.	No pain, only stiffness and some loss of motion.
1	30°–40°	Dorsal osteophytes as main finding; minimal joint narrowing, flattening of the metatarsal head, and/or periarticular sclerosis.	Mild and/or intermittent pain and stiffness at maximal dorsiflexion and/or plantar flexion of the joint.
2	10°–30°	Periarticular osteophytes with mild to moderate joint narrowing, flattening of the metatarsal head, and/or periarticular sclerosis.	Moderate to severe pain and stiffness with a more pronounced frequency; pain evoked near end range of motion of the joint.
3	≤10°	Same as grade 2 but with the addition of cystic changes subchondral and likely sesamoid irregularities.	Nearly constant pain and stiffness with the pain being elicited with end range of motion, but not at midrange.
4	≤10°	Same as grade 3.	Same as grade 3 but with pain present at midrange of passive motion of the joint.

Table 2.

		Arthroplasty (AP)	Arthrodesis (AD)
Age average (y.)		54.8	63.1
Gender		Female – 17 (85%), male – 3 (15%).	Female – 17 (81%), male – 4 (19%).
Time until full recovery (months)		2.8	3.9 p = 0.006
Additional symptoms after operation	**Did not occur**	11 (55%)	11 (52%)
	Pain	5 (25%)	3 (14%)
	Numbing	2 (10%)	1 (5%)
	Deformation	2 (10%)	7 (33%)

Table 3.

	Arthroplasty (AP)			Arthrodesis (AD)			p value
	Mean	Statistical deviation	Median	Mean	Statistical deviation	Median	
SEFAS	3.71	0.36	3.83	3.38	0.5	3.5	0.14
SF12 Physical Score	49.77	8.03	53.75	39.89	10.83	41.4	**0.02**
SF12 Mental Score	50.27	8.56	51.8	49.15	11.63	53	0.729

Discussion

There is still no consensus on the optimal treatment method for Hallux Rigidus in the literature. The main goal of surgery is a pain-free joint, functional limb, and satisfied patient. For many years, I MTP joint arthrodesis has been considered as the gold standards of the treatment, due to satisfactory results and pain relief [6, 14]. However, after this procedure, complete loss of motion in the I MTP joint occurs, making it more difficult to fit footwear of desired height [15]. An alternative option is joint-preserving resection arthroplasty (AP) which preserves joint motion. After a technically successful surgery, patients can lean on the big toe while maintaining push-off force [16]. However, a significant risk of complications is observed in the literature such as: joint instability, metatarsalgia (13.9%), or cock-up deformity of the toe (9.7%) [15, 17].

Before surgical treatment, patients are informed about the advantages and disadvantages of the surgery. Only when well-informed and understanding the benefits and drawbacks of the procedure, they can choose a procedure that best fits their lifestyle and expectations. It is crucial for the physician to listen to the patient's preferences, understand their expectations, and assist them in selecting the appropriate surgical option. Since AP surgery preserves joint function, it may be more attractive for physically active, younger individuals [16].

After analysing the survey data, it can be concluded that both surgical methods are effective and improve the functional status of patients (80% of patients expressed satisfaction with postoperative results in both groups). With improved understanding of foot biomechanics, refined surgical techniques and more targeted patient selection, satisfaction with AP surgery significantly increases from 71.6 to 93.6 points from 100 according to AOFAS scale [15]. The results of AD surgery are also satisfactory and can reach up to 89% [18].

In this study, patients with moderate to severe Hallux Rigidus (HR) were examined. According to the literature, the best results of AD are achieved in cases of severe (3–4°) I MTP arthrosis [8, 14]. AP is potentially associated with more frequent late complications (AP – 26.3%, AD – 23.1%) [12] and more frequent revisions (AP – from 4% to 11.6%, AD – from 3% to 9.6%) [19]. Additionally, in cases of advanced HR, joint-preserving surgeries may not ensure sufficient joint functionality, or it may be temporary. In such cases, a revision surgery may be required – AD of the joint. During this study, no revision surgeries were needed, no infections and nonunions were observed. Statistically insignificant postoperative symptoms were identified in less than a half of the examined patients: mild to moderate pain during movement (19% of patients), numbness in the incision area (7% of patients), and suboptimal position or deformities of the big toe (more frequent in the AD group, 33%).

During the study, a statistically significant difference was found in the recovery time of foot function when evaluating the outcome. After the surgery, a period of 3–4 weeks is recommended, during which the patient should protect the foot and walk moderately, avoiding putting weight on the forefoot. Patients who underwent AD surgery had a longer functional recovery period by approximately 1 month compared to patients who underwent AP (3.9 months and 2.8 months, $p = 0.006$). Throughout this period, patients may

not be able to fully engage in daily activities and use the operated limb. This can be significant for working-age patients who wish to return to work as quick as possible. Based on the results of the study, it can be assumed that the functional outcomes of AD in the early postoperative period are inferior to AP, as assessed by patients' subjective evaluation.

Based on the results of the SEFAS scale, a tendency can be observed that patients who underwent AP surgery had slightly better functional outcome ($p = 0.14$). This hypothesis is supported by other studies that used similar questionnaires, such as the study by Santos Silva et al., which used the AOFAS-HMI scale (AP – 89.7 points, AD – 65.7 points; $p < 0.001$) [20]. This may be related to the fact that patients selected for AP procedure were properly screened. Older patients more often choose AD procedure to avoid additional surgeries, as their priority is to eliminate the cause of pain in a single procedure.

Assessment of quality of life helps to evaluate overall health and well-being of patients. The obtained Mental Score average did not significantly differ between the compared groups: AP – 50.27 points, AD – 49.15 points. According to the authors of the analogous SF-36 scale, this is almost equivalent to the general population average of 50 points. These results indicate that patients' perception of their health and well-being after our surgeries is generally satisfactory. However, there were statistically significant differences in the Physical Score: AP group – 49.77 points, AD group – 39.89 points ($p = 0.02$). Inferior results in the AD group could be associated with patients' older age (AP – 54.8 years, AD – 63.1 years), concurrent comorbidities, and lack of motivation for postoperative rehabilitation. AP patients were younger, had a more active lifestyle, possibly had fewer risk factors, and were more motivated to return to daily activities. All these differences contribute to better outcomes in terms of quality of life.

During this study, questionnaires were chosen that allow for a reliable assessment of patients' physical condition and quality of life [9, 13]. The collected data enables comparison of the effectiveness of the discussed surgeries and can be useful for further research into more effective surgical techniques, patient satisfaction, as well as for investigating postoperative complications and their frequency. The obtained results are relevant on a national scale, as there are few studies comparing these surgeries in the literature, and no such studies have been conducted in Lithuania.

Our study has certain limitations. During the study, a relatively small sample size of only 41 patients was analysed, so more accurate results would require a larger study group. Additionally, the surveys were conducted 2–4 years after the surgery, which is an intermediate time period. In order to study long-term results, a longer follow-up period after the surgery would be necessary. Furthermore, revision surgeries and early complications were not assessed in this study. Inclusion of these criteria in future research would help to assess the superiority of AP or AD more accurately.

In clinical practice, it is important for a surgeon to select the appropriate surgical method, taking into consideration the patient's expectations and lifestyle characteristics. Individual assessment of patient criteria and thorough preoperative patient informing can lead to better clinical outcomes. For younger, working-age, physically active patients who do not respond to conservative measures, AP surgery is recommended as the first-choice method. Patients with limited physical activity and increased risk of complications in future revision surgeries, especially elderly ones, may be more suitable for AD surgery.

Conclusion

Both surgical treatment methods have satisfactory outcomes. According to subjective patient surveys, individuals who underwent AP surgery reported better physical condition compared to those who underwent AD surgery. Additionally, the recovery period of full foot function is significantly longer in AD patients' group compared to AP. To obtain more accurate results, a larger sample size and a longer follow-up period are needed.

References

1. Roddy E, Thomas MJ, Marshall M, Rathod T, Myers H, Menz HB, Thomas E, Peat G. The Population Prevalence of Symptomatic Radiographic Foot Osteoarthritis in Community-Dwelling Older Adults: Cross-Sectional Findings from the Clinical Assessment Study of the Foot. Ann Rheum Dis 2015; 74(1): 156–163.

2. Senga Y, Nishimura A, Ito N, Kitaura Y, Sudo A. Prevalence of and Risk Factors for Hallux Rigidus: A Cross-Sectional Study in Japan. BMC Musculoskelet Disord 2021; 22(1): 786.

3. Ho B, Baumhauer J. Hallux Rigidus. EFORT Open Rev 2017; 2(1): 13–20.

4. Lam A, Chan JJ, Surace MF, Vulcano E. Hallux Rigidus: How do I Approach It? World J Orthop 2017; 8(5): 364–371.

5. Shurnas PS. Hallux Rigidus: Etiology, Biomechanics, and Nonoperative Treatment. Foot and Ankle Clinics 2009; 14(1): 1–8.

6. Chraim M, Bock P, Alrabai HM, Trnka HJ. Long-Term Outcome of First Metatarsophalangeal Joint Fusion in the Treatment of Severe Hallux Rigidus. Int Orthop 2016; 40(11): 2401–2408.

7. Clews CNL, Kingsford AC, Samaras DJ. Autogenous Capsular Interpositional Arthroplasty Surgery for Painful Hallux Rigidus: Assessing Changes in Range of Motion and Postoperative Foot Health. J Foot Ankle Surg 2015; 54(1): 29–36.

8. Coughlin MJ, Shurnas PS. Hallux Rigidus. Grading and Long-Term Results of Operative Treatment. J Bone Joint Surg Am 2003; 85(11): 2072–2088.

9. Cöster MC, Bremander A, Rosengren BE, Magnusson H, Carlsson Å, Karlsson MK. Validity, Reliability, and Responsiveness of the Self-Reported Foot and Ankle Score (SEFAS) in Forefoot, Hindfoot, and Ankle Disorders. Acta Orthop 2014; 85(2): 187–194.

10. Je W, Cd S. The MOS 36-item Short-form Health Survey (SF-36). I. Conceptual Framework and Item Selection. Medical Care [Internet] 1992 [cited 2023]; 30(6). Available at: <https://pubmed.ncbi.nlm.nih.gov/1593914/>.

11. Gandek B, Ware JE, Aaronson NK, Alonso J, Apolone G, Bjorner J, Brazier J, Bullinger M, Fukuhara S, Kaasa S, Leplège A, Sullivan M. Tests of Data Quality, Scaling Assumptions, and Reliability of the SF-36 in Eleven Countries: Results from the IQOLA Project. International Quality of Life Assessment. J Clin Epidemiol 1998; 51(11): 1149–1158.

12. Stevens J, de Bot RTAL, Hermus JPS, van Rhijn LW, Witlox AM. Clinical Outcome Following Total Joint Replacement and Arthrodesis for Hallux Rigidus: A Systematic Review. JBJS Rev 2017; 5(11): e2.

13. Ware JE, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: Construction of Scales and Preliminary Tests of Reliability and Validity. Medical Care 1996; 34(3): 220–233.

14. Massimi S, Caravelli S, Fuiano M, Pungetti C, Mosca M, Zaffagnini S. Management of High-Grade Hallux Rigidus: A Narrative Review of the Literature. Musculoskelet Surg 2020; 104(3): 237–243.

15. Patel HA, Kalra R, Johnson JL, Huntley SR, Lehtonen EJ, McGwin G, Naranje S, Shah A. Is Interposition Arthroplasty a Viable Option for Treatment of Moderate to Severe Hallux Rigidus? – A Systematic Review and Meta-Analysis. Foot Ankle Surg 2019; 25(5): 571–579.

16. Johnson MD, Brage ME. Total Toe Replacement in the United States: What Is Known and What Is on the Horizon. Foot Ankle Clin 2016; 21(2): 249–266.

17. Artioli E, Mazzotti A, Zielli S, Bonelli S, Arceri A, Geraci G, Faldini C. Keller's Arthroplasty for Hallux Rigidus: A Systematic Review. Foot Ankle Surg 2022; 28(4): 526–533.

18. Doty J, Coughlin M, Hirose C, Kemp T. Hallux Metatarsophalangeal Joint Arthrodesis with a Hybrid Locking Plate and a Plantar Neutralization Screw: A Prospective Study. Foot Ankle Int 2013; 34(11): 1535–1540.

19. He Y, Shan F, Fan C, Zeng X, Yang G, Tang B. Effectiveness of the First Metatarsophalangeal Joint Arthrodesis Versus Arthroplasty for Rheumatoid Forefoot Deformity: A Systematic Review and Meta-Analysis of Comparative Studies. J Foot Ankle Surg 2021; 60(4): 787–794.

20. Santos Silva M, Rodrigues-Pinto R, Barros LH, Sousa A, Muras J. Arthrodesis *versus* Arthroplasty of the First Metatarsophalangeal Joint in the Treatment of Hallux Rigidus – A Comparative Study of Appropriately Selected Patients. Rev Bras Ortop (Sao Paulo) 2020; 55(1): 40–47.