Research Article

The effect of transtibial and transportal techniques of graft positioning on strength and proprioception in subjects submitted to anterior cruciate ligament reconstruction surgery

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Abstract

Objective: Investigate the effect of ACL reconstruction surgery on proprioception and muscle strength, by comparing transtibial and transporal techniques in the pre and postoperative periods of 3, 6 and 12 months. Hypothesis was that transportal technique would present better results since it provides greater anteroposterior and rotational stability.

Methods: 100 patients with ACL injury, divided in Transtibial Group and Transportal Group. Evaluations were performed through Joint Position Sense, Isokinetic Test, International Knee Documentation Committee (IKDC) and Tegner Lysholm Knee Scoring Scale. Patients were assessed at 3, 6 and 12 months after surgical procedure.

Results: All variables from all tests only presented better outcomes when comparing the uninjured group to ACL limb, regardless the time or group (p >0.05). Except for IKDC, which showed difference between all instants of time (p <0.01).

Conclusions: The present research do not support the hypothesis that the Transportal way provides better results than Transtibial in terms of muscle strength and proprioception. Furthermore, none of these values improved after 12 months after ACL reconstruction surgery, regardless the method employed. Such findings may help further review the minimum patients’ discharging time to their normal routine, mainly regarded to sports.
Introduction

The knee is commonly affected by traumatic events, and the Anterior Cruciate Ligament (ACL) rupture represents a significant amount of lesions [1]. Annually, around 200,000 ACL injuries are reported in the United States of America [2] and in Europe. It ranges from 36.9 to 78 individuals per 100,000 inhabitants [3,4]. The ACL plays an important role in joint stability because it mechanically restricts the anterior translation and the internal rotation of the tibia [5,6]. Besides, the ACL provides proprioceptive information regarding the joint [7,8].

The ACL has mechanoreceptors [9], whose function is the acquisition of afferent signals[10], contributing to knee proprioception [8,11]. Hence, rupturing the ACL reduces the afferent information taken to the cortex, thus altering proprioception and consequently the ability to detect movement [12,13]. In addition, there is the inhibition of the motoneurons responsible for controlling the muscles located around the joint [14,15], thereby altering motor control and muscle strength [16]. Several studies compared the proprioceptive acuity and muscle strength of healthy knees to those suffering from ACL insufficiency. They were able to state there were proprioceptive and strength deficits for the injured knees [17,18]. Thus, the success of reconstruction techniques and rehabilitation programs after ACL injury may depend not only on restoring mechanical stability, muscle strength and joint motion range, but also on proprioception recovery.

ACL reconstruction surgery results are well documented in several studies, depicting good or excellent outcomes related to mechanical stability, joint function, proprioception and muscle strength. Nevertheless, there are still some concerns regarding the graft choice and tunnel positioning technique, which would present better results [19,20]. Although the transtibial technique has been successfully used for years in ACL reconstruction, some studies have recently reported an improved recovery of mechanical stability and knee joint function, using the transportal technique [21,22]. Conversely, other studies did not find differences between those techniques regarding the same variables [23,24]. So, the technique of choice, which should present better clinical results, including joint function, proprioception recovery and muscle strength is still controversial. Additionally, the outcomes of the surgical technique on the muscle strength and proprioception recovery after ACL reconstruction are still not confirmed. Thus, this study aimed at investigating the effect of transtibial and transportal ACL reconstruction techniques on joint proprioception and muscle strength. The study hypothesis was that the transportal technique would present better results since it provides greater anteroposterior and rotational stability.

Materials and methods

Study design

This is a prospective, observational, longitudinal study with evaluations on the surgery’s eve (pre-op) and 3, 6 and 12 months after the surgical procedure. This observational study took place between May 2018 and June 2019.

Subjects

100 male and female patients from the Instituto Nacional de Traumatología e Ortopedia Jamil Haddad (INTO) were randomly chosen, all of them with unilateral ACL rupture. 10 patients out of the 100 initial patients were excluded because they did not meet the study criteria, remaining 90. These 90 were randomly divided into two groups of 45 participants according to the surgical procedure to be performed, namely Transtibial Group and Transportal Group. Amongst the Transtibial Group, 2 participants were excluded after the surgical procedure because they have presented osteomyelitis and 3 gave up participating in the study in the third month. In the Transportal Group, 2 were excluded because they presented infection at the surgical points and 3 gave up participating in the study in the third month. Therefore, only 40 participants remained in each group until the study was completed.

The researchers did not know to which group any participant was assigned until data was thoroughly collected and patients from both groups had similar surgical incisions, so, it was not possible to distinguish the techniques by ectoscopy. The inclusion criteria for the study were: (1) age between 18 and 40 years old; (2) diagnosis of isolated ACL rupture confirmed by magnetic resonance imaging (patients with other associated lesions were excluded because our objective was to study only the implications of the ACL lesion); (3) positive Lachman and Drawer tests (all participants having been clinically evaluated by the same physician); (4) skeletally mature with closed physis; (5) no previous surgery on the affected knee, no degenerative changes on arthroscopy; (6) no associated ligament injuries; (7) no morbid obesity. The exclusion criteria were: (1) previous ACL reconstruction surgery; (2) presence of any type of associated lower limb injury, including meniscal injury, chondral injury or articular cartilage degeneration (characterized by joint cracking in any compartment of the knee) and/or knee osteoarthritis signs diagnosed by resonance; (3) being involved in any therapeutic practice to improve muscle strength, motor control or balance at the beginning of the project, since any of such activities might, somehow, affect or even improve either proprioception or knee strength. Beyond turning the sample into a non-homogeneous one, 6 months without any physical activity would be enough to normalize all participants regarding the variables studied and (4) have practiced physical activity regularly in the past six months (so that the sample was homogeneous and because practicing any physical activity could positively or negatively influence the studied variables). Characteristics of the patients from each group see Table 1.

Surgical technique

All ACL reconstructions were performed by the same surgeon. Patients were operated under spinal anesthesia associated with femoral nerve block. Surgeries were performed under ischemia with a pneumatic cuff calibrated at 300 mmHg, applied to the proximal region of the affected limb, prior to the collection of autologous flexor tendons (semitendinosus and gracilis). Tendons were prepared in a quadruple graft and pretensioning was performed after femoral fixation and,
prior to tibial fixation, by the repetition of 30 mobilization cycles throughout the entire knee movement arc. For both techniques, the tibial tunnel was made in a similar way, with the knee positioned at 90 degree of flexion, using a 55 degrees inclination tibial guide.

For the transtibial technique, the conventional femoral guide was introduced into the tibial tunnel to keep the knee flexed at 90 degrees, and positioned at the medial wall posterior border of the lateral femoral condyle. After having observed the anatomical parameters, the guidewire was positioned around 11 hours for the right knee or 1 hour for the left knee, followed by perforation of the femoral tunnel. Regarding the transportal technique, while maintaining the knee flexed in 90 degrees with visualization through the accessory medial portal, the native ACL center was marked (anatomical positioning) through the conventional anteromedial portal. With the knee flexed between 120 and 130 degrees, the guidewire was then positioned at the previously marked point (around 10 hours for the right knee or 2 hours for the left knee), followed by femoral tunnel perforation. Computer Tomography showed the grafts’ desired position for both techniques for all subjects.

In all ligament reconstructions, femoral fixation was performed by cortical suspension technique (Endobutton® Smith & Nephew, Andover, MA, USA). The tibial fixation was performed with a bioabsorbable interference screw, 1 mm larger than the tibial tunnel diameter (Milagro® DePuy-Synthes).

Rehabilitation program

A functional progression was followed as an systematic sequence of activities which enable the acquisition or re-acquisition of necessary skills for the safe and effective performance of athletic endeavors as well as daily living activities. In other words, the patient needed to master a simple activity before moving on to a more demanding one. All patients followed the same physical therapy rehabilitation protocol according to the review carried out by Cavanaugh and Powers [25] in the postoperative period. The progresses were individualized, where some patients were ready to advance earlier than others, since each person has their own individual time response to stimuli. Being performed 3 times a week, each session lasted one hour.

Table 1: presents main characteristics of the patients from each group.

<table>
<thead>
<tr>
<th>Data</th>
<th>Transtibial Group (TTG)</th>
<th>Transportal Group (TPG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>29.9 ± 6.81 years</td>
<td>29.6 ± 6.26 years</td>
</tr>
<tr>
<td>Height</td>
<td>173.1 ± 7.28 cm</td>
<td>174.5 ± 9.43 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>82.8 ± 15.13 kg</td>
<td>79.0 ± 19.06 kg</td>
</tr>
<tr>
<td>Time from injury to surgery</td>
<td>28.5 ± 11.35 months</td>
<td>34.2 ± 12.48 months</td>
</tr>
<tr>
<td>Cause of lesion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recreational soccer (55%) falls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>basketball accident (10%),</td>
<td></td>
<td></td>
</tr>
<tr>
<td>descending ladder (10%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recreational football (70%) falls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorcycle accident (10%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>descending ladder (5%)</td>
<td></td>
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</tbody>
</table>

Evaluation

All patients were evaluated the day before the surgery and 3, 6 and 12 months after the surgical procedure. Prior to the beginning of the evaluations, all participants signed an Informed Consent Form, in which the study objectives and experimental conditions were described in detail. The study was approved by the Institutional Ethics Board (CAAE number 28206414.1.0000.5273). This study is in accordance with the Helsinki Declaration.

Data were collected prospectively as the patients were operated, by a blinded researcher. Patients from both groups had similar surgical incisions, so that it was not possible to the participants and to the researchers differ from the surgical techniques by ectoscopy. One member of the team, who did not participate in the evaluations, had the key to the group’s composition, which was later revealed during the statistical analysis.

Measurements of knee function

International Knee Documentation Committee (IKDC) [26] and Tegner Lysholm Knee Scoring Scale [27], both translated and validated into Portuguese [28,29], were used for functional evaluation of the injured knees [28,29].

Joint position sense

Joint Position Sense test (JPS) was performed on an isokinetic dynamometer (CSMI®, HUMAC NORM®, MA, USA). The subjects were placed either seated or in the ventral position, with the lateral femoral condyle aligned with the device’s rotation axis and the ankle attached to the rod of the knee evaluation accessory by a velcro® strip. Then, the joint’s range of motion (ROM) was determined. After that, the individuals had to experience and subsequently reproduce, with voluntary movements, two positions, 20% and 50% of the ROM (0% = maximum extension). Variations of ± 5° around the target position were allowed, and if this margin was violated, a new attempt was made. A total of 5 attempts for target were carried. The Extension and Flexion Joint Position knee tests (JPS-EXT – Figure 1) (JPS–FLE – Figure 2) were performed. Both operated and healthy contralateral limbs were evaluated. Throughout the procedure, patients remained blindfolded to avoid any visual feedback as well as the JPS and limb tests order were randomized. The individual error value for each attempt was determined by the difference between the position reproduced and the position experienced. Proprioceptive performance was determined by the Absolute Error (AE), Schmidt e Lee [30] described in detail the calculations of each variable. EA was obtained as the mean of module of the individual errors and determines the accuracy of the individual to reproduce the position:

$$EA = \frac{\sum |xi - M|}{n}$$

EA: Absolute Error; xi: Position Reproduced; M: Position Experienced; n: number of repetitions of the attempts of the joint position sense.

Muscle torque was measured by means of isokinetic tests conducted with a dynamometer (CSMI®, HUMAC NORM®, MA, EUA). Subjects were positioned seated, with the hip at approximately 90° allowing the whole back to touch the backrest and they were kept to the seat by means of belts. Prior to each test and calibration procedures, the participant performed a warm-up familiarization process which comprised knee extension and flexion at low efforts. The test for right and left limbs comprised one set of five repetitions producing maximal exertion at the 60°/s in concentric-concentric mode, and extension preceded flexion. Recorded torque signals were processed by a custom-built routine built in Matlab 7.02c (MathWorks Inc., USA). Signals were low-pass filtered (cut off frequency of 10Hz) by a 2nd order Butterworth applied in forward and reverse directions, allowing a zero-phase. Following, the extension–flexion cycles were automatically identified and the maximal value of the peak torque encountered from all repetitions was computed (PT). The PT values were normalized by body weight for further analyses.

Statistical analysis

First, a paired t-test was performed to compare the variation between the time of injury and surgery between the two groups.

The following variables were analyzed in the study: PT for extensors and flexors, ROM and absolute errors for the JPS test obtained in 20% of the ROM for extensors and flexors (E20E and E20F, respectively) as well as in 50% of the ROM (E50E and E50F, respectively). Lysholm and IKDC scores were also evaluated. All variables were tested for normality by the Henze–Zirkler’s Multivariate Normality Test. Lysholm and IKDC scores and ROM did not present normal distribution (p <0.001). An unpaired t-test was used to compare PT and JPS variables before intervention, between TTG and TPG, as well as to compare operated versus healthy limbs.

Comparisons between the measures taken at the four moments (preop, 3, 6 and 12 months) considering the effect of the intervention and time were performed using two-way ANOVA, one for repeated measures (moments) and another independent (type of intervention). Sphericity was checked and, if not verified, the Greenhouse-Geisser correction was applied. Bonferroni posthoc test was used for pairs’ comparison, when applicable. The calculated effect size was determined between the tests performed in successive periods, as well as between the results obtained 12 months after the preoperative moments. Friedman’s ANOVA test was applied to the measurements of Lysholm, IKDC and ROM.

Statistical significance level was established as p ≤ 0.05 for all tests. All analyzes were performed using the SPSS® (IBM®. Chicago, IL, USA).

Results

While to injury until surgery

No significant difference was found between groups (p = 0.468) (Table 2).

<table>
<thead>
<tr>
<th>Months</th>
<th>TTG</th>
<th>TPG</th>
<th>p</th>
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<tbody>
<tr>
<td></td>
<td>6.8 ± 2.93</td>
<td>6.2 ± 2.25</td>
<td>0.468</td>
</tr>
</tbody>
</table>

TTG: Transtibial group, TPG: Transportal group.

ROM

No significant effect of time was found in the ROM for extension or flexion in both surgical techniques (p > 0.250) (Figure 3). Main effect was not found for moment, nor for group for extension or flexion in both surgical techniques, nor interaction (Figure 3).

Muscle torque

During the preoperative test, PT values were significantly higher in the healthy limbs, both for the extensors (F = 2.520; DF = 4; p = 0.001) and flexors (F = 4.518; DF = 2; p = 0.04) (Table 3).
The operated limb presented significant time influence over knee extensors PT (F = 5.297; DF = 2; p = 0.002), but not of the surgical technique (F = 3.304; DF = 2; p = 0.185). Further post hoc test showed a significant reduction in PT when compared the moments before (PRE) and three months after surgery (p = 0.049), and the moments 3 and 6 months after surgery (p < 0.001, figure 4). Similar results were found in the knee flexors PT, which also presented time influence (F = 3.119; DF = 2; p < 0.001) yet not of the surgical technique (F = 4.802; DF = 2; p = 0.179), with a significant PT reduction when compared the moments before (pre) and 3 months after surgery (p = 0.049) and a PT increase when compared after 3 and 6 months of surgery (p <0.001, figure 4). In both groups (TTG and TPG) we did not find any differences between knee extensors and flexors PT when compared the moments before (pre) and 12 months after surgery. Effect sizes were considered trivial between each pair of tests and between the PRE and 12M tests (Table 4).

For the healthy contralateral limb, knee extensors PT presented influence of time (F = 6.676; DF = 2; p = 0.018), but not of the surgical technique (F = 23.177; DF = 2; p = 0.983). Similar results occurred for the knee flexors PT (F = 6.451; DF = 2; p = 0.014 - time, and F=5.322; DF = 2; p = 0.106 - intervention). The PT patterns of knee extensors and flexors decreased after three months of surgery and increased after six months of surgery. They were similar to the observed in the operated limb (figure 4). Effect sizes also followed pattern similar to those obtained in the operated limb (Table 5).

**Joint position sense – knee extensors**

E20E received influence of time (F = 5.851; DF = 2; p = 0.02), but not of the surgical technique (F = 9.292; DF = 2; p = 0.590), presenting a significant reduction 12 months after treatment in both groups (p = 0.025). In addition, this variable presented different behavior between the groups (TTG and TPG) from the first to the second measurement (Figure 5; Table 4).

The E50E was not influenced by surgical technique (F = 9.771; DF = 2; p = 0.804), but changed over time, as evidenced by decreases between the 3rd and 6th month (p <0.001), and between the 6th and 12th months (p <0.001), in the TTG approach (Figure 5). Notwithstanding, there was no difference in E50E between the moments before (PRE) and 12 months after surgery in both groups, which presented small effect sizes (Table 4).

**Joint position sense – knee flexors**

There was no difference in E20F between surgical techniques (F = 8.543; DF = 2; p = 0.853). However, there was an increase in E20F when compared the moments before (PRE) and 3 months after surgery, and a reduction between 3 and 6 months after surgery (p <0.001; Figure 5). Besides, there was no difference in E20F between the moments before (PRE) and 12 months after surgery (p = 0.436), which presented small effect size (Table 4).

For the E50F, there was also no treatment influence, but there was a difference between all the tests (Figure 5). It was the only variable to suffer a significant reduction when comparing the pre-test with the one after 12 months of surgery (p <0.001).

For the E50F, there was also no treatment influence, but there was a difference between both groups regarding E20E (F = 5.032; DF = 2; p = 0.583). Analyses found influence of time on E50F (F = 2.366; DF = 2; p = 0.179), represented by a reduction after 12 months (p = 0.001) in TTG (p = 0.004). Regarding flexion, there was also a reduction after 12 months when compared to the measurement before surgery (PRE) (p <0.001).

**Knee function**

The Lysholm score improved in both groups when compared...
before (PRE) and 12 months after surgery (p<0.001) moments. However, analysis did not evidence any difference between TTG and TPG (p = 0.883) (Figure 7).

IKDC improved over time in both groups (p <0.001, for all comparisons). However, there was no difference between TTG and TPG.

Discussion

ACL reconstruction can be performed both by transportal and trantibial techniques. However, there are conflicting evidences in the literature regarding knee joint function, stability, proprioception recovery and muscle strength after ACL reconstruction using any of the techniques. In the TT technique, the femoral tunnel is drilled through the previously constructed tibial tunnel, imposing tibial and femoral tunnels interdependence and, therefore, the same orientation to both [31,32]. This has led to criticisms to the method because the reconstructed ACL differs from its actual anatomy, and additionally, due to the graft’s vertical positioning (11 hours for the right knee and 14 hours for the left), which does not restore rotational stability although recovering anteroposterior stability.
Hence, TP technique has been advocated as presenting better results, once tibial and femoral tunnels are constructed independently, aiming at miming the actual ACL anatomy. Moreover, several advantages have been attributed to this technique, as a more anatomical femoral tunnel, possibility of independent femoral and tibial tunnels, more graft horizontal positioning and greater anteroposterior and rotational stability. Recent studies with cadavers and clinical studies in humans, which compared both techniques, reported better results for the TP technique, especially regarding the greater rotational stability. However, most of these studies evaluated the knee functionality with no muscular overload. Besides, despite TP presents anatomical reconstructed ACL closer to its actual native status, the results of this procedure concerning muscle strength and proprioception are of great importance to the patient.

The present study, similarly to other investigations, examined proprioception and muscle strength in patients submitted to ACL reconstruction using transtibial or transportal techniques. Also, it included the recovery follow-up after 3, 6 and 12 months. Data from preoperative condition presented no between-group difference, showing that both groups were very homogeneous, thus allowing a better qualification on the between-group post-operative comparisons. To Mir, et al., the reestablishment of ACL mechanical function leads to immediate knee kinematics improvement and, by the same token, of proprioception and muscular strength. Furthermore, studies have reported restoration of proprioception after ACL reconstruction, albeit none of them mentioned which of the two surgical techniques was used. Conversely, some researchers were able to report deficit of the injured when compared the normal knee after ACL reconstruction, which is consistent with our results. In the present study, all variables related to strength and proprioception from all tests only presented better outcomes when comparing the uninjured to ACL limb, regardless time or group. These results are also in accordance with most of the studies that compared the two techniques using subjective functionality
questionnaires and did not find differences between the two surgical techniques [23,24]. Indeed, to best of our knowledge, only demonstrated more TP effectiveness than TT technique regarding proprioception improvement using subjective functionality questionnaires. Robin, et al [39], in a systematic review, showed advantages and disadvantages between TT and TP techniques and, although differences between the methods have already been reported, the authors concluded there is no golden standard technique for the best graft positioning and for the femoral tunnel drilling. This leads one to believe that ACL reconstruction technique should be individualized according to clinical parameters and each patients’ physical demands. However, studies pointing which technique matches each patient profile are still missing.

Considering the TP reconstruction technique recovers the anteroposterior stability at least equal to the TT yet presenting superiority in the knee rotational stabilization [31,32], one might expect that such technique provides biomechanical recovery closer to the normal knee. This belief formed the basis of our first hypothesis that TP would present superiority when compared to TT regarding the recovery of proprioception and muscular strength. However, the results of the present work revealed no improvement of the two variables up to 12 months. Likewise, these variables showed no difference when compared the TT and TP groups and after three months following the surgery patients of both groups, there was a reduction in proprioception and muscle strength, possibly due to pain, inactivity and/or surgical trauma. After such period, a gradual improvement was observed in both groups but without between–groups difference. Moreover, even after one year, the increase in proprioception and muscle strength for both groups were not significant when compared to the moment before surgery, leading us to believe that surgery was not able to restore knee proprioception and to allow patient to increase muscle strength within the period investigated, regardless the surgical technique used. Valeriani, et al. [40], have shown that proprioceptive deficiency after ACL rupture is related to a loss of cortical somatosensory evoked potentials, emphasising the important role of neurophysiological, cortical mechanisms on musculoskeletal function after ligament damage. Mogendorff and Brand [41] complement that the joints’ sensory innervation does not recover after the injury, which might justify the non-recovery of proprioception found.

One of the main goals of treatment after ACL injury is the patient’s return to their pre-injury functional state. In this regard, the unrestricted return to daily life activities and even sports are usually allowed 6 months after surgery [42,43]. Notwithstanding, the graft ligamentization seems to take more than 6 months [44], whereas graft stiffness and knee muscles strength can be impaired far beyond that time [45,46]. The results of the present work demonstrated that quadriceps and hamstrings strength do not significantly increase for at least 12 months after surgery. The concept developed for Dye [47], of the ‘envelope of function’, which incorporates and connects the principle of load transference and tissue homeostasis in order to visually represent the knee functional capacity. The envelope is defined as the load and frequency distribution within a safe range to ensure overall tissue homeostasis. In this context, a voluntary activation deficit after a joint injury may be a central regulatory attempt by the knee to inhibit muscle groups moving an injured joint in order to ensure that loading under the critical ‘envelope will not lead to further joint or softtissue damage. The theory of a central nervous inhibition after joint damage is supported by the finding of bilateral voluntary activation deficits, and by experimental evidence for a tonic descending inhibition through spinal neurones induced by artificial arthritis of the knee [48,49]. This may explain why non-recovery of muscle strength, as Urbach, et al. [50], suggests in his study. Or maybe, a longer period for a full patient recovery might be further considered, regardless the type of surgical procedure employed.

On the other hand, it should be stressed out that the functional analysis results, based on self-reported scales, showed a significant increase when comparing to the moments before and 12 months after surgery for patients who underwent surgery by both techniques. Kim, et al. [51], in a similar study showed similar results to the present study, not finding significant differences between the TT and TP techniques, even though the TP technique has shown superior results. The study by Mirzatolooei [52], which used the same functional parameters, found results contrary to ours, but it was not informed by the researcher if any rehabilitation process was carried out by the participants, an important factor that may influence the results.

As limitations of this study, it is possible that the scientifically validated, more usable, rehabilitation process employed in this research is not enough to promote significant improvements in proprioception and muscle strength. Also, it is possible that the small number of subjects in each group contributed since we did not find any significant differences between groups.

**Conclusion**

The results for the present study do not support the hypothesis that TP ACL reconstruction gives better results than TT technique in terms of muscle strength and proprioception. Furthermore, none of these valences improved after 12 months of surgery for ACL reconstruction, regardless the method employed. The only improvement achieved by the surgeries was the personal sensation of wellness. These findings may help to further review the minimum time allowed to the patients to return to their normal activities, mainly regarded to sports.

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