Comparison between Cortical Button versus Interference Screw Fixation for Anterior Cruciate Ligament Reconstruction using Quadrupled Hamstring Tendon Graft: A Clinical Performance Analysis

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Abstract: ***Background**: Anterior cruciate ligament (ACL) reconstruction using hamstring autograft is currently the most prevalent option in treating ACL injury, however there are still difference in opinion in the current literature regarding the optimal femoral fixation method. **Purpose**: To compare knee stability and functional outcome scores at 12 months after ACL reconstruction using either cortical button or interference screw as a femoral fixation technique. **Study design**: Retrospective non-randomized comparative study. **Method**: 60 patients selected from January 2018-Decemeber 2019 that fulfilled the inclusion criteria, were retrospectively evaluated and distributed into two groups, according to the femoral fixation method in ACL reconstruction (cortical button, CB vs interference screw, IS). The primary outcome measure was knee stability measured with the anterior drawer test, Lachman test and pivot-shift test, and the secondary outcome measure was the functional outcome scores, as determined by the Tegner Activity Scale, Lysholm Knee Score, International Knee Documentation Committee (IKDC) score, Knee Injury and Osteoarthritis Outcome Score and Anterior Cruciate Ligament Return to Sports after Injury score, at 12 months post surgery. **Result**: Equal number of cases were selected for each treatment method (30 cortical button vs 30 interference screw). The knee stability measurements showed no difference between groups at 12 months of follow up, (P=1.000) for anterior drawer, Lachman and pivot-shift tests. Secondary clinical outcome measures also showed no statistical difference between groups at the end of the same follow up period, Tegner (P=0.19), Lysholm (P=0.23), IKDC (P=0.13), KOOS (P=0.34) and ACL RSI (P=0.12). **Conclusion**: Our results showed no significant difference in knee stability and clinical outcomes comparing cortical button versus interference screw in hamstring ACL reconstruction.***

Keywords: anterior cruciate ligament reconstruction; hamstring autograft; cortical button; interference screw; femoral fixation

1. Introduction

Anterior cruciate ligament (ACL) injury is a common sports-related injury occurring in young athletes in Thailand, with an annual incidence that is estimated to be more than 10-20 per 100,000 cases per year[1]. This injury prevents the athlete from returning to the pre-injury levels of activity, subsequently developing functional knee deficits, muscular weaknesses, atrophyand finally going on to develop knee osteoarthritis[2]. Thus, ACL reconstruction plays an important role in improving the functional outcome of these affected individuals.

ACL reconstruction using hamstring (HT) has emerged as a commonly utilized graft of choice for many sport surgeons. Many literatures have shown that HT is equivalent or slightly superior to a BPTB autograft[3,4,5]. The reported advantages of a HT autograft is the reduction in donor site morbidity, less quadriceps weakness, fewer anterior knee pain, and a more comparable graft size in relation to the native ACL[6,7]. Biomechanical studies have also confirmed that the HT graft has an average load failure of 4200N, which is well above an intact ACL (2160N)[8,9].

In spite the favour towards the use of this graft, there is amaindisadvantages regarding tendon to bone healing, which can take up to 12 weeks for graft incorporation, as opposed to a direct bone to bone healing in a BPTB graft[10]. Hamstring graft failure rates range from 4% to 27.3%, and can be caused by poor initial fixation of the soft tissue graft[11]. Motion of the ACL graft within a bone tunnel has been shown to be detrimental to graft healing and may lead to tunnel widening, leading to graft slippage or failure before biological fixation has occurred[12]. Therefore, graft fixation is paramount to exert an essential influence on the mechanical behavior of the HT during the early period of reconstruction, since it is thought to a decisive factor in the timing of rehabilitation and return to desired activity levels[13].

Currently there are many options of femoral-sided soft tissue graft fixation method, which can be categorized as follows: compression (intratunnel), expansion, and suspension (extratunnel)[14]. The two most generally used at our centre are; the compression type [bio-interference screw (IS)] and suspension type [cortical button (CB)]. However despite these options, a gold standard for femoral fixation has not yet been identifiedand remains controversial.Biomechanical and animal studies have identified potential benefits and drawbacks to eachfixation technique.Some argue that CB offers the best predictable results in terms of graft elongation, fixation strength and stiffness, with a superior biomechanical property compared to IS. Meanwhile, others reported that maximum failure load was significantly lower in the IS group and that CB constructs may have lateral wall impingement that is accentuated by tunnel widening, leading to increase graft failures[15,16].

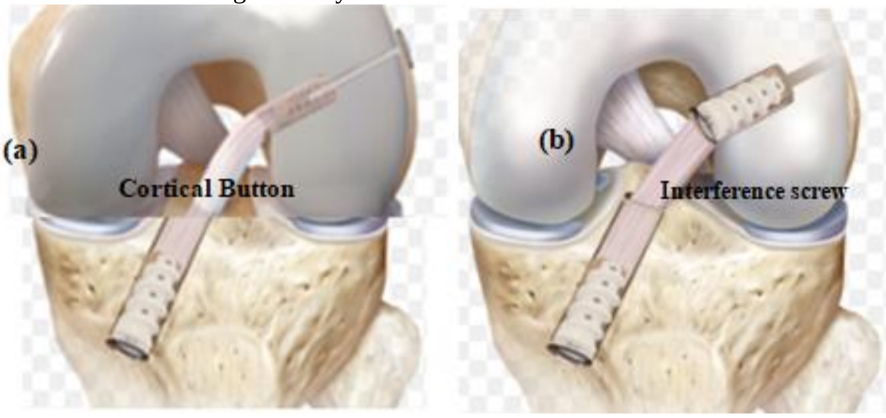

Figure 1: Femoral fixation in ACL reconstruction using (a) cortical button, and b (interference screw)

Several systemic reviews and meta-analysis have demonstrated mixed results in terms of stability and clinical performance when comparing both methods, hencethere is a significant need to provide an up to date analysis on which is the best preferred option of treatment in our local population here in Thailand.

The primary outcome measure of this study is to determine if there is a significant difference in postoperative knee stability for CB versus IS fixation of a quadrupled HT autograft in ACL reconstruction done at 12 months, and the secondary outcome measure looks into the clinical outcome scores between both groups at the same period.

Our Hypothesis is that interference screw should perform better in knee stability and clinical outcome scores between both the fixation methods.

2. Methodology

2.1 Study Selection

This was a retrospective non-randomized comparative study that was carried out at the Orthopaedics and Physiotherapy Department, Chiang Mai University (CMU), Thailand.

This study included patients admitted to CMU that underwent an anatomical single bundle ACL reconstructive surgery using either CB or IS, with quadrupled hamstring autograft from January 2018 to December 2019.

Patients selected had to have either a fixed looped cortical button (CB) ora bio-absorbable interference screw (IS) as the femoral fixation device, and only a bio-absorbable interference screw as the tibia fixation device.

2.2 Eligibility Criteria

The study population was adults over 18 years and below 40, including both genders. Selected patients had pre-operative findings as follows: anterior drawer test > 3 mm, Lachman test > 3 mm, and pivot shift test + (glide).

The surgery was performed by a qualified Orthopaedic Sports surgeon using the same technique. Furthermore, we also included patients who underwent the same post-ACL reconstruction rehabilitation therapy, which includes pain and swelling control, restoration of the normal range of motion, and development of muscle strength.

Patients who had a revision ACL and those with concomitant ipsilateral ligamentous injury were excluded from this study. Furthermore, patients who underwent subtotal or total meniscectomyor meniscus repair for meniscus injury or cartilage procedures were also excluded from this study to avoid confounding factors.

2.3 Data Analysis & Statistics

Outcome Measures

All the patients were assessed both clinically and functionally pre- and post-surgery (at 12 months). The primary outcome measures werethe Anterior Drawer test at 90^0 of flexion, Lachman test at 25^0 of flexion, and Pivot Shift test. The Anterior Drawer and Lachman tests results were graded as 0 (1-2 mm), 1 (3-5 mm), 2 (6-10 mm), and 3 (>10 mm). The Pivot Shift test results were graded as 0 (equal), 1 (glide), 2 (clunk), and 3 (gross).

The secondary outcome measure at 12 months after the ACL reconstruction,were the International Knee Documentation Committee (IKDC) score, ACL RSI (Return to Sport after Injury) score, KOOS (Knee Injury and Osteoarthritis Outcome Score), Lysholm knee scoring scale (LKS), and Tegner activity level scale.For these categorical data, each category was treated as an individual binaryvariable, and the frequency and 95% CI of each categorywere computed for each study.

Results were analyzed by SPSS using the two sample and paired t-testsmethod.

3. Result

Sixty cases that fulfilled the criteria were analysed throughout the study. Among them, 46 were males and 16 were females. Equal number of cases were selected for each treatment method. 30 patients were each pooled into the CB and IS groups respectively.

3.1 Demography

Demographically, the groups were comparable with respect to the mean age, CB 31.4 (20 – 45) vs IS 28.2 (19 – 45) (P =0.09), except gender where both groups had significantly higher male gender, CB 24 males (80%) vs 6 females (20%) and IS 22 males (73.3%) vs 8 females (26.7%) (P < 0.05) (refer Table 1).

Table 1: Baseline characteristics

	Cortical Button (n,%)	Interference Screw (n,%)
Gender:		
Male	24 (80.0)	22 (73.3)
Female	6 (20.0)	8 (26.7)
Age, mean (range)	31.4 (20 – 45)	28.2 (19 – 45)

3.2 Anterior Drawers Test

Pre operatively all patients (CB 30 ptsvs IS 30 pts) had an anterior drawers of grade 2 or more. Post operatively, both groups had23 patientswith a grade 0 (76.7%) vs 7 patients(23.3%) with a grade 1 anterior drawer laxity. No patients from each group had a grade 2 laxity or more. There were improvement in clinical outcome in each treatment group (refer Table 2);however it was **not statistically significant** when comparing between both the CB vs IS groups (76% vs 76%, respectively; P=1.000).

3.3 Lachman Test

Pre operatively all patients (CB 30 ptsvs IS 30 pts) had a Lachmantest of grade 2 or more. Post operatively, 23 patients (76.7%) had a grade 0 vs 7 patients (23.3%) had a grade 1 in the CB group, whereas25 patients (83.3%) had a grade 0 vs 5 patients (16.7%) had a grade 1 in the IS group.No patients from each group had a Lachmangrade 2 laxity or more. There were improvement in clinical outcome in each treatment group (refer Table 2); however it was **not statistically significant**when comparing between both the CB vs IS groups (76.7% vs 83.3%, respectively: P=1.000).

3.4 Pivot-Shift Test

Pre operatively all patients (CB 30 ptsvs IS 30 pts) had a grade 1 and above positive pivot-shift test. Post operatively 24 patients (80.0%) had a grade 0 vs 6 patients (20.0%) had a grade 1 in the CB group, whereas 23 patients (76.7%) had a grade 0 vs 7 patients (23.3%) had a grade 1 in the IS group.No patients from each group had a pivot-shift grade 2 laxity or more. There wereimprovement in clinical outcome in each treatment group (refer Table 2); however it was **not statistically significant**when comparingbetween both the CB vs IS groups (80.0% vs 76.7%, respectively: P=1.000).

Table 2: Association between test and type of femoral fixation method

Variable	Cortical Button	Interference Screw	p-value [a]
Gender			**0.542**
Male	24 (80.0)	22 (73.3)	
Female	6 (20.0)	8 (26.7)	
Ant Drawer Test			**1.000**
Grade 0	23 (76.7)	23 (76.7)	
Grade 1	7 (23.3)	7 (23.3)	
Lachman Test			**1.000**
Grade 0	23 (76.7)	25 (83.3)	
Grade 1	7 (23.3)	5 (16.7)	
Pivot Shift Test			**1.000**
Grade 0	24 (80.0)	23 (76.7)	
Grade 1	6 (20.0)	7 (23.3)	
Age	31.4 (~7.1)	28.2 (~7.2)	**0.091**

[a] Pearson Chi-Square Test for Independence

3.5 Tegner Score

In the CB group, the mean pre op Tegner score was 4.13 (3 – 5) and the mean post op score was 6.4 (5 – 8). In the IS group, the mean pre op Tegner score was 4.13 (3 – 5) and the mean post op score was 6.7 (6 – 8). There were clinical improvements in each group that were significant (refer Table 3); however it was **not statistically significant** when comparing between both the CB vs IS groups (6.4 [95% CI, 6.0-6.7] vs 6.7 [95% CI, 6.4-6.9], respectively; P=0.194).

Table 3: Change of Tegner Score within the type of femoral fixation method

Variable	Pre-Tegner	Post-Tegner	Mean diff (95% CI)	p-value [a]
Fixation				
CB	4.13 (3-5)	6.40 (5-8)	2.3 (1.9-2.6)	**<0.001**
IS	18.53 (2.59)	16.46 (2.96)	2.5 (2.1-2.8)	**<0.001**

[a] Paired t-test

3.6 Lysholm Score

In the CB group, the mean pre op Lysholm score was 59.2 (32 – 75) and the mean post op score was 86.8 (64 – 99). In the IS group, the mean pre op Lysholm score was 57.1 (35 – 80) and the mean post op score was 89.5 (74 – 99). There were clinical improvements in each group that were significant (refer Table 4); however it was **not statistically significant** when comparing between both the CB vs IS groups (86.8 [95% CI, 83.0-90.5] vs 89.5 [95% CI, 86.7-92.2], respectively; P=0.230).

Table 4: Change of Lysholm Score within the type of femoral fixation method

Variable	Pre-Lysholm	Post-Lysholm	Mean diff (95% CI)	p-value [a]
Fixation				
CB	59.2 (32-75)	86.8 (64-99)	27.6 (22.5-32.6)	**<0.001**
IS	57.1 (35-80)	89.5 (74-99)	32.4 (27.1-37.6)	**<0.001**

[a] Paired t-test

3.7 IKDC Score

In the CB group, the mean pre op IKDC score was 62.4 (47.2 – 78.2) and the mean post op score was 83.2 (50.1 – 97.1). In the IS group, the mean pre op IKDC score was 55.6 (38.5 – 83.6) and the mean post op score was 79.2 (50.8 –

94.1). There were clinical improvements in each group that were significant (refer Table 5); however it was **not statistically significant** when comparing between both the CB vs IS groups (83.2 [95% CI, 79.0-87.4] vs 79.2 [95% CI, 75.7-82.6], respectively; P=0.137).

Table 5: Change of IKDC Score within the type of femoral fixation method

Variable	Pre-IKDC	Post-IKDC	Mean diff (95% CI)	*p*-value [a]
Fixation				
CB	62.4 (47.2-78.2)	83.2 (50.1-97.1)	20.7 (16.1-25.4)	**<0.001**
IS	55.6 (38.5-83.6)	79.2 (50.8-94.1)	23.6 (17.0-30.1)	**<0.001**

[a] Paired t-test

3.8 KOOS Score

In the CB group, the mean pre op KOOS score was 67.1 (52 – 81) and the mean post op score was 88.7 (60 – 98). In the IS group, the mean pre op KOOS score was 72.5 (55 – 90) and the mean post op score was 86.9 (60 – 98). There were clinical improvements in each group that were significant (refer Table 6); however it was **not statistically significant** when comparing between both the CB vs IS groups (88.7 [95% CI, 85.6-91.9] vs 86.9 [95% CI, 84.4-89.3], respectively; P=0.341).

Table 6: Change of KOOS Score within the type of femoral fixation method

Variable	Pre-KOOS	Post-KOOS	Mean diff (95% CI)	*p*-value [a]
Fixation				
CB	67.1 (52-81)	88.7 (60-98)	21.6 (17.6-25.6)	**<0.001**
IS	72.5 (50-90)	86.9 (60-98)	19.7 (16.2-23.2)	**<0.001**

[a] Paired t-test

3.9 ACL RSI

In the CB group, the mean pre op ACL RSI score was 48.8 (26.4 – 86.6) and the mean post op score was 66.4 (39.2 – 96.6). In the IS group, the mean pre op ACL RSI score was 54.7 (24.5 – 92.3) and the mean post op score was 75.4 (49.2 – 99.1). There were clinical improvements in each group that were significant (refer Table 7); however it was **not statistically significant** when comparing between both the CB vs IS groups (66.4 [95% CI, 62.3-70.5] vs 75.4 [95% CI, 70.3-80.4], respectively; P=0.124).

Table 7: Change of ACL RSI Score within the type of femoral fixation method

Variable	Pre-ACL RSI	Post-ACL RSI	Mean diff (95% CI)	*p*-value [a]
Fixation				
CB	48.8 (26.4-86.6)	66.4 (39.2-96.6)	17.6 (13.4-21.8)	**<0.001**
IS	54.7 (24.5-92.3)	75.4 (49.2-99.1)	20.6 (16.2-25.0)	**<0.001**

[a] Paired t-test

3.10 Graft Failure

There were no reports of graft failure in both the CB and IS groups after 12 months post ACL reconstruction.

Table 8: Association between Secondary outcome measures and femoral fixation methods

Variable	Cortical Button	Interference Screw	*p*-value [a]
TEGNER	6.4 (6.0-6.7)	6.7 (6.4-6.9)	**0.194**
LYSOLM	86.8 (83.0-90.5)	89.5 (86.7-92.2)	**0.230**
IKDC	83.2 (79.0-87.4)	79.2 (75.7-82.6)	**0.137**
KOOS	88.7 (85.6-91.9)	86.9 (84.4-89.3)	**0.341**
ACL RSI	64.4 (62.3-70.5)	75.4 (70.3-80.4)	**0.124**

[a] Pearson Chi-Square Test for Independence

4. Discussion

The primary and secondary outcome measures of interest in our study were the post-operative knee stability and clinical outcome scores,on follow up at exactly 12 months post-surgery. From our results, we can summarize that there were**no statistically significance differences** in the performance analysis in relation to cortical button versus interference screw.

Femoral fixation plays a vital role in a robust ACL reconstruction and an optimum strength is necessary to allow for an early range of motion post reconstruction.The two types techniques used for femoral-sided graft fixation in our study are suspensory cortical buttons (CB) and interference screws (IS).

CB is an implantable metal buttons that is placed on the opposite cortical surface. It is available as fixed- or adjustable-length loop devices that are tightened intra-operatively. Iteffectively resists displacement because it is cortically anchored. Residual displacement is likely the result of deformation of the continuous polyester loop[17]. Because resistance vectors are oriented toward the cortex-implant interface, the load concentration is inversely proportional to the implant contact surface area. As a result, the failure load and stiffness increase with the implant diameter and number of contact points[18].

Fixation with an interference screw is achieved by engaging the tendon with the screw threads and compressing it against the cortical bone or bone tunnel wall[17]. By anatomically affixing the tendon to bone near the joint line, interference screws improve joint stability. Interference fixation generates increased local pressure around the tendon-cancellous bone interface, which is thought to augment biologic healing[18].Material properties, geometry, core diameter, pitch or thread height, length, placement,bone mineral density and insertional torque play an important role in preventing graft pullout[19].

To date, the fixation construct of choice remains unclear because clinical evidence is limited by variability in surgical technique and outcomes reporting.We hypnotized that IS should perform better on the notion thata strong and secure graft tunnel to bone healing by the presence of atight screw, as opposed to a button fixation, because there is a concern of tunnel osteolysis that occurs commonly at the tunnel aperture in the early post-operative periods following ACL reconstruction[20].Furthermore, biomechanical studies suggest that ACL grafts fixed closer to the intra-articular aperture result in more stable constructs[21]. Such results are not surprising, all else being equal, because the stiffness of a construct is inversely proportional to its working length[22]. L'Insalata et al.[23] described the ''windshield wiper effect'' as a mismatch of graft and tunnel sizes at the articular tunnel entrance that may allow synovial fluid to enter the tunnel, leading to micromotion and eventual tunnel expansion. This allows the graft to move sagittally back and forth between the tunnel margins as the knee flexes and extends. In addition, previous studies have described the phenomenon of the ''bungee effect'' secondary to longitudinal graft motion, which may reduce stability and construct stiffness and also lead to tunnel widening[24,25]. The IS fixation at the aperture results in a shorter total length of the graft construct, which increases stiffness of the knee, if the elastic modulus of the graft is assumed to be constant over its length, and alsohas a highest mean values regarding graft elongation[18].A recent study from the Norwegian Knee Ligament Registry found an increased rate of failure with CB fixation[26] possibly due tograft-tunnel motion when using distant extratunnel fixation sites.

Having said that, CB fixation does have itstheoretical advantages as well.Suspensory femoral fixation implants are reliable and provide predictable femoral-sided fixation in ACL reconstruction. Biomechanical analysisshows a significantly higher yield load and ultimate failure load than IS[27]. Milano et al.[18] found higher load to failure, increased stiffness, and decreased graft elongation compared to interference screw fixation. CB also shows a greatly variable mechanical behavior, fixation strength and stiffness[28].A biomechanical study by Monaco et al.[29] evaluated various methods of hamstring graft fixation and found that suspensory femoral fixation withstood forces that are similar to those experienced during postoperative rehabilitation and that failures occurred mostly at the tibial side when utilizing aperture fixation. The reason being is that footprint area is compromised during aperture fixation (using interference screws at the joint line) because the screws themselves fill much of the footprint, displacing graft collagen. This results in less anatomic restoration of the footprint.Moreover, graft slippage can occur in screws of smaller diameters, whereas graft damage in larger diameter screws[30]. In contrast, a meta-analysis by Prodromos et al.[31] found that the strongest construct for hamstring tendon autografts was button femoral fixation with aperture tibial fixation.

Most published studies report that cortical button fixation results in greater tunnel widening when compared with other hamstring fixation devices. Buelowet al.[32] compared tunnel widening for intratunnel fixation using bioabsorbable interference screws versus cortical button fixation. They found that femoral tunnel widening was 76% at a minimum of 2 years' follow-up.However,Choi et al.[33] recently showed that the cause of tunnel widening in the cortical button group may not be simply explained by a "long fixation distance" theory. They reported the outcomes of 171 consecutive patients after hamstring ACL reconstruction with cortical button femoral fixation. A 15-mm loop was used in 20 patients, a 20-mm loop in 53, a 25-mm loop in 58, and loop greater than 30 mm in 40. Two years after surgery, no significant differences in tunnel widening were present according to the length of the cortical button loop among the 4 groups.

There have been other reviews regarding femoral graft fixation that shows no difference between both fixation methods. Colvin et al.[34] performed a meta-analysis of femoral fixation and found no significance difference between aperture fixation and suspensory fixation with respect to IKDC scores and clinical failures. Han et al.[35] reviewed and analyzed level 1 and 2 evidence studies with a minimum 2-year follow-up to evaluate intratunnel and extratunnel fixation. The groups showed no significant difference regarding objective IKDC grades, Lysholm and Tegner scores, instrumented anterior laxity and pivot-shift test findings, and return-to-sport timing. The aperture group displayed earlier full weightbearing and jogging/running; however, return-to-sport timing did not differ between the groups.Saccomanno et al.[36] found no differences between CBand IS fixation, apart from increased tunnel widening in the CB group, which was shown not to affect short-term knee function, or correlate to clinical outcomes.More recently a network meta-analysis by Hurley ETet al.[37] showed no difference in failure rate, knee stability, functional outcomes or incidence of revision procedures between different methods of femoral fixation techniques, which included CB and IS femoral fixations techniques of hamstring tendon autografts in ACL reconstruction. And a Bayesian network meta-analysis by Lei Yan et al.[38] concluded that there were no statistical difference in performance among the CP, CB and IS femoral fixation methods, although the IS was more likely to perform better than CB and CP based on the analysis of outcome measures from the included studies.

4.1 Limitations

There were some limitations in our study. (1) The sample size was small for each group to be compared against; (2) the absence of KT-1000 arthrometer measurement to give a more accurate result in terms of anterior laxity; and (3) the relatively short (12 months) last follow up evaluation.

5. Conclusion

Our study showed that there was no difference in terms of knee stability and functional outcome between CB and IS femoral fixation of hamstring autografts in ACL reconstruction. This finding suggests that both fixation methods are comparable and predictable in terms of the functional outcomes, and the decision should be based on the surgeon preference and experience.Achieving successful healing of soft tissue to bone requires a thorough understanding of all aspects of the fixation construct. Although biomechanical data guide the choice of fixation methods, these methods should be corroborated by continued randomized controlled trials that incorporate both objective and subjective outcome measures.

Additional Information

Disclosure

Human subjects: Consent was obtained by all participants in this study. Ethics approval was obtained from the Ethics Committee at Chiang Mai University, Thailand. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authorsdeclare the following: **Payment/services info:** This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. **Financial relationships:** All authors have declaredthat they have no financial relationships at present or within the previous three years with anyorganizations that might have an interest in the submitted work. **Other relationships:** All authors havedeclared that there are no other relationships or activities that could appear to have influenced thesubmitted work.

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