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Original Article

Biomechanical Study: Resistance Comparison of Posterior Antiglide Plate and Lateral Plate on Synthetic Bone Models Simulating Danis-Weber B Malleolar Fractures

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ABSTRACT

Objective: The purpose of this study was to compare different positions of plates in lateral malleolar Danis-Weber B fractures on synthetic bone: a lateral plate and a posterior antiglide plate. *Methods*: Short oblique fractures of distal fibula at the level of the syndesmosys were simulated with a fibular osteotomy in sixteen synthetic fibula bones (Synbone®). Eight fractures were fixed with lateral plating associated with an independent lag screw, and the other eight were fixed with posterior antiglide plating with a lag screw through the plate. A strain gage was installed at the center of each plate at the osteotomy site. Supination and external rotation forces were applied to each of the two groups at the bend. *Results*: The lateral position plate group suffered more deformity in response to supination forces compared to the group with the posterior antiglide plate, but this result was not statistically significant. In the tests with external rotation forces, the posterior antiglide plating group had significantly higher resistance ($p < 0.05$). *Conclusion*: When subjected to external rotation forces, osteosynthesis with posterior antiglide plate models simulating type B fractures of the lateral malleolus of the ankle is more resistant than that of the neutralization plate.

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Introduction

The incidence of ankle fractures is increasing, and studies have shown that fracture incidence among the elderly has doubled over the last 40 years.[1] Among athletes, both professional and amateur, the incidence has also increased. Due to its position and characteristics, the ankle is subject to numerous traumas, and its fracture is the most frequent among the load-bearing joints.[2] Risk factors for ankle fracture were elucidated by performing a complementary analysis of multiple cases.[3-5] Most of the cases consisted of isolated malleolar fractures, representing two thirds of total ankle fractures. One fourth of the patients presented fractures in the two malleoli, and 7% of the patients presented bimalleolar fractures with the third posterior fragment. Open fractures are rare and represent only 2% of all ankle fractures.[6]

In various studies, the importance of anatomic reduction and rigid fixation of these fractures to achieve complete functional restitution has been highlighted.[2,7-9] Danis-Weber type-B fractures, adopted by the AO group, are quite frequent.[10,11] In the literature, several ways to stabilize this type of fracture have been suggested: a single interfragmentary lag screw, associated interfragmentary screws, tension bands, intramedullary wire or nails, and intramedullary screw or support plates and screws.[10,12-14]

Within this last option, there are several ways to install the synthesis material. The most common method involves two platings. A one-third tubular neutralization plate is placed laterally and associated with an independent interfragmentary lag screw outside the plate and a posterolateral antiglide plate can be attached with an interfragmentary lag screw through the plate.[15]

Several researchers have conducted trials to compare these two techniques with the use of plates and screws. Some of them use case series and group them into the techniques employed.[12,16] Other researchers have conducted biomechanical studies with cadaveric bones.[9,14] There are many advantages to posterior plating over lateral plating. With lateral orientation, there is the possibility of intra-articular positioning of the distal screws.[17,18] There is also greater incidence of surgical wound dehiscence using the lateral technique.[16] Greater resistance has been observed with posterior plating[17], and a greater number of patients report satisfactory results regarding the positioning of the plate in the posterior position.[19]

There are several arguments in favor of posteriorly placing the plate with ankle fractures, and these arguments have motivated us to attempt to prove these supposed advantages. Our study provides a quantitative analysis concerning the difference in mechanical efficiency obtained with the different dispositions in the osteosynthesis of the lateral malleolus of the ankle.

Objective

This study aims to simluate Danis-Weber type-B fractures and assess the mechanical resistance of osteosynthesis with interfragmentary lag screw and lateral and posterior plates, which are subject to supination stress and external rotation.

Material and Methods

The present study used anatomical models of synthetic fibula bones that simulate the shape and bone characteristics of human fibulas (Synbone®).[20] Sixteen fibulas of the same size and density were used and subjected to a simulated Danis-Weber type-B fracture. Oblique cuts from the anterior cortical bone to the posterior bone were made by using an oscillatory saw with a 1-mm thick blade at the height of the tibiotalar joint of each model (Fig. 1).

The fibulas were divided into two groups. In Group 1, the failure was attached with an interfragmentary lag screw associated with a one-third tubular plate that containing six holes (for 3.5 mm screws) with six cortical screws, which is used for neutralization, on the lateral surface of the fibula (lateral plate; Fig. 2A). In Group 2, the failure was attached with an interfragmentary screw through a one-third tubular plate containing four holes (for 3.5 mm screws) with three more cortical screws in the posterior surface of the fibula (antiglide posterior plate; Fig. 2B).

After the fixation of the two groups, a strain gauge was installed in the center of each plate (Fig. 2C). This device was able to measure slight variations in tension, and it also measured the deformity in the center of the plate to assess the deforming forces.

The first experimental trial was performed with the fibulas of Group 1 (lateral plates). Each fibula was positioned in a stabilization device, together with the tibia, which was also synthetic. These fibulas were subject to bending strengths (simulating supination efforts) from 5 to 60 kgf, progressively increasing the load every 5 kgf. Data were collected by the ADS 500 conditioner by Lynx Tecnologia, and data analysis was performed by the Linx AqDados© and Linx AqDAnalysis© software. The same trial was conducted with Group 2 fibulas (posterior plate; Figs. 3A and 3B).

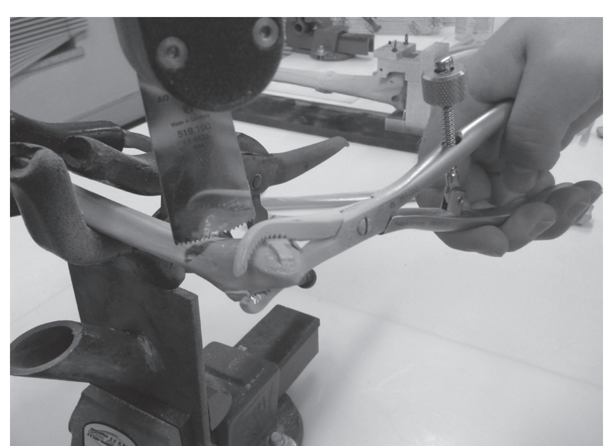


Fig. 1 - A right synthetic fibula was subjected to a simulation of a fracture using a 1-mm thick saw.

A B C

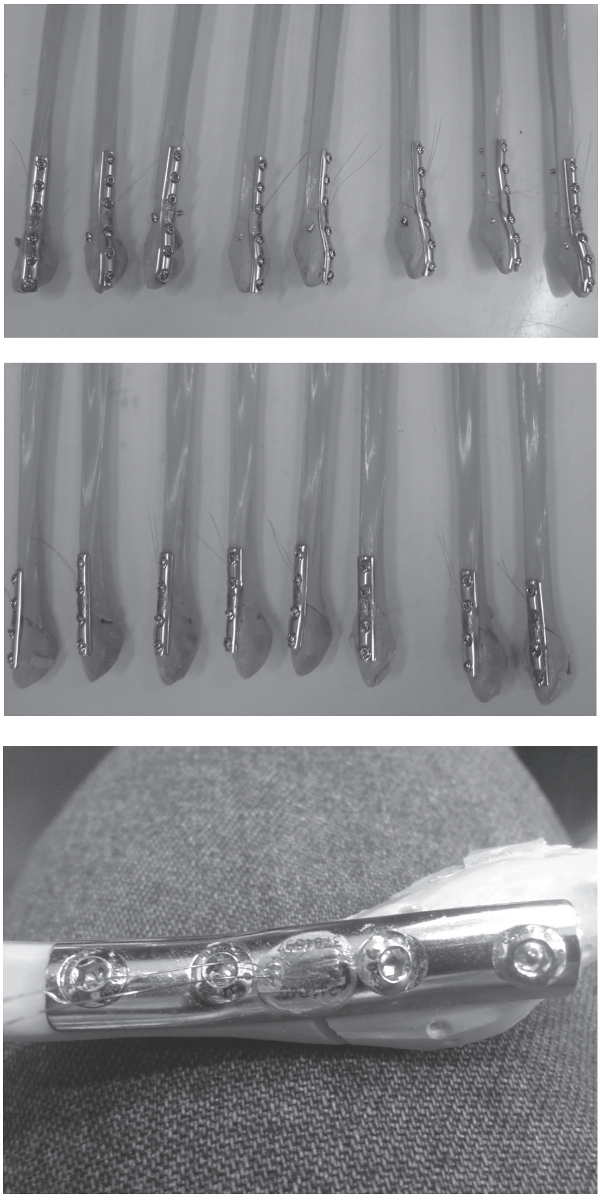


Fig. 2 - Right synthetic fibulas. (A) fixation of a lateral plate with six holes. (B) fixation of a posterior plate with six holes. In both groups, it is possible to observe small electrodes fixed to the plates. (C) A strain gauge was used to measure the deformation in the center of the plates.

A

B C

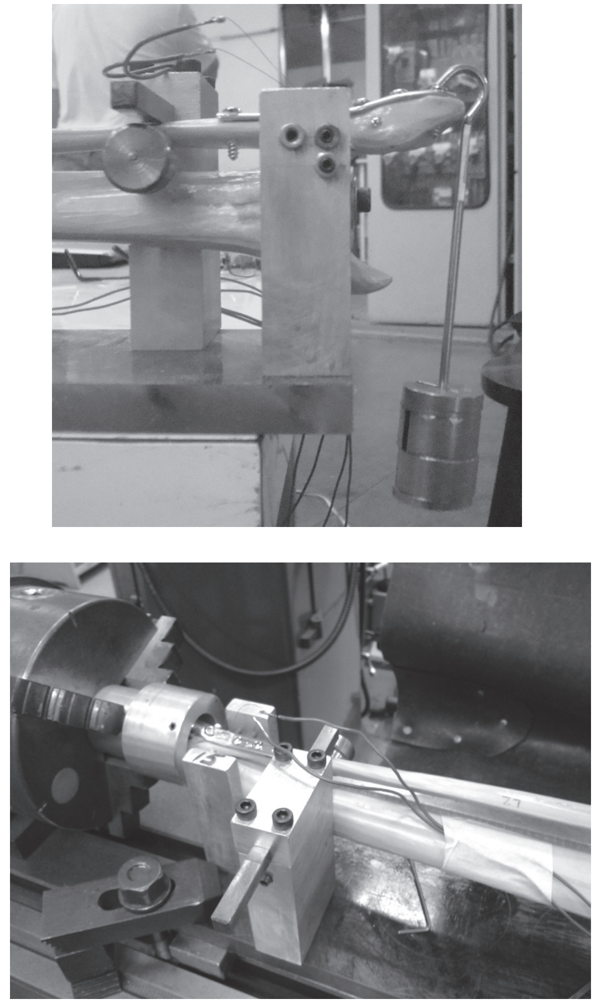


Fig. 3 - Illustration of the trials. (A) equipment used for data acquisition and analysis. (B) weight applied to the fibula, with simulation of supination effort. (C) fibula inserted in the mandrel used to apply torsional forces.

The second experimental trial was performed with a mandrel connected to the distal end of the fibula, which made it possible to apply torsional strain (simulation of an external rotation effort). Strain was measured up to 30 degrees of torsion in 5-degree steps. Measurement of the deformity of the osteosyntheses was performed by the same software and strain gauges. The trial was first performed with Group 1 and then with Group 2 (Fig. 3C).

Data collected by the programs was statistically and graphically analyzed using Student's t test for two unpaired samples. Microsoft Office Excel© software and the OpenEpi.[21] website were used for the analyses.

Results

The deformations measured by the devices that we used were calculated in millistrains, which are micrometric

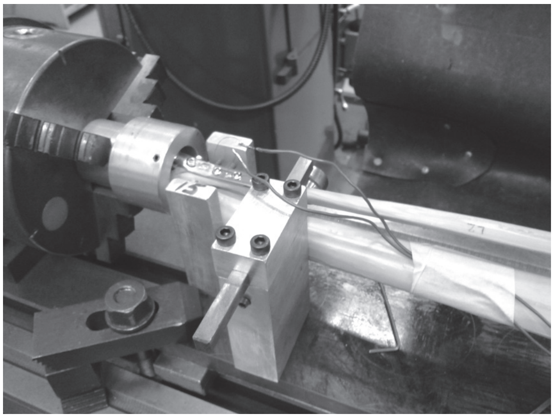


Fig. 4 - Example of the results provided by the Linx AqDAnalysis© software; deformation in millistrain (on the vertical axis) and elapsed time of the trial (horizontal axis); each plateau represents a degree of applied strength; return to initial state is observed after the removal of the deforming forces.

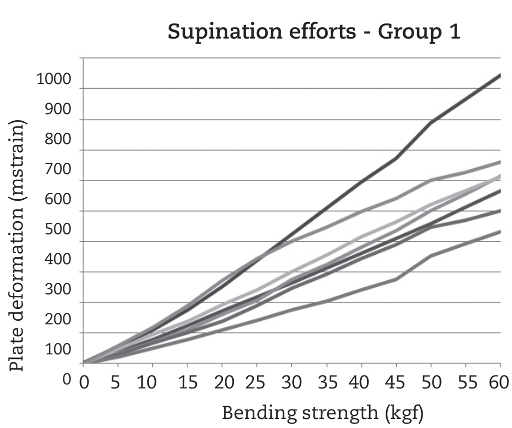
deformation units per surface. In the great majority of the cases, these microscopic deformations were not followed by macroscopic deformations (Fig. 4). In each group, one specimen presented fatigue and plastic deformation, which affected the measurement of the microdeformations of the strain gauges, and these data were excluded from the graphical and statistical analyses.

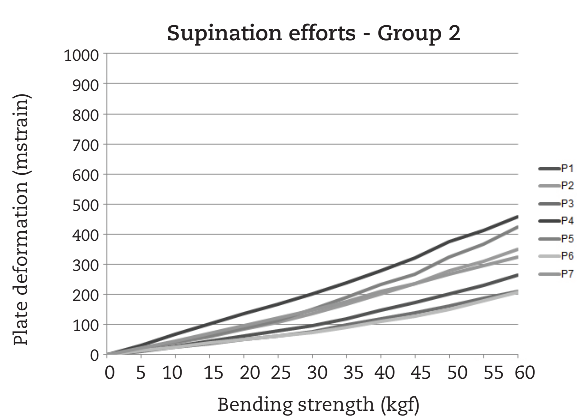
The measurements calculated by the strain gauges were tabulated by the software mentioned, and the data were transformed into graphics. Table 1 displays the data obtained in the first trial and the deformations of Group 1 (lateral plate).

Fig. 5 displays the conversion of Table 1, which was performed with supination forces from 5 to 60 kg. Similarly, Fig. 6 provides the data from Group 2 specimens, also in supination, (posterior plate). Figs. 7 and 8 present the data obtained in the external rotation trials. Fig. 7 includes the data gathered from Group 1 (lateral plate), and Fig. 8 presents the data from Group 2 (posterior plate). The graphics are presented in pairs, to allow a visual analysis of the results.

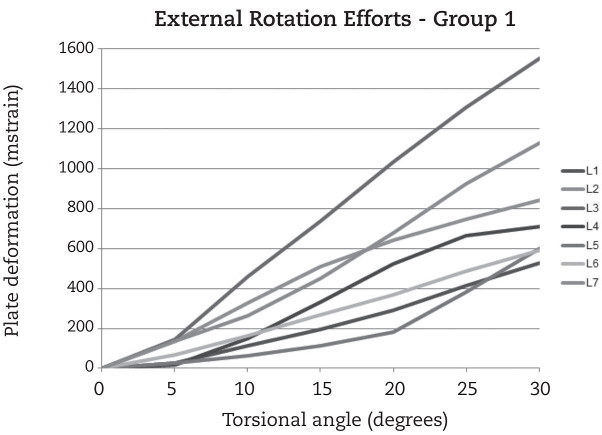
Table 1 - Deformations measured (in millistrains) of the samples of group 1 in the first trial regarding the deforming strength (in kgf).

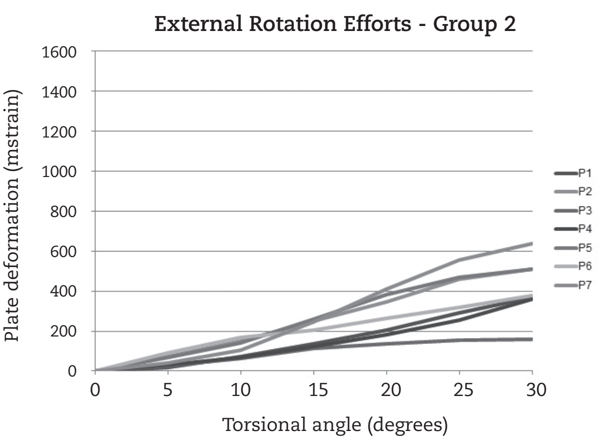
	Samples of Group 1						
	L1	L2	L3	L4	L5	L6	L7
Applied force (kgf)							
0	0.813333	1.3	0.956667	2.26	1.17	0.31	1.11
5	39.82	32.99333	31.96	56.68333	24.00333	48.10667	60.50333
10	79.96333	71.61667	67.64	110.2833	50.81	95.45667	119.9167
15	123.91	110.2467	101.64	177.42	78.77	140.2967	191.5367
20	172.25	162.8	140.11	254.6367	111.78	192.67	274.2533
25	218.2167	208.3167	189.4833	339.1033	141.8667	242.5633	343.0733
30	265.2767	275.82	247.8233	423.4933	175.5633	301.6667	401.0767
35	313.6733	325.4067	292.1033	508.6867	205.9133	354.53	446.0467
40	361.0567	382.18	345.1033	595.6067	242.1767	416.1867	498.4333
45	410.1833	435.92	390.4233	672.4967	276.8467	463.7233	542.0567
50	458.99	502.17	446.6667	788.63	354.4067	520.0433	599.9633
55	513.81	556.0233	470.3467	866.1567	392.7867	566.25	627.1333
60	566.2133	615.6767	500.4933	944.9733	432.4967	611.29	661.1167





Figs. 5 and 6 - Deformation of Groups 1 and 2, respectively, in the first trial, due to the deforming strength in supination.





Figs. 7 and 8 - Deformation of Groups 1 and 2, respectively, in the second trial, due to the deforming angle in the torsional force.

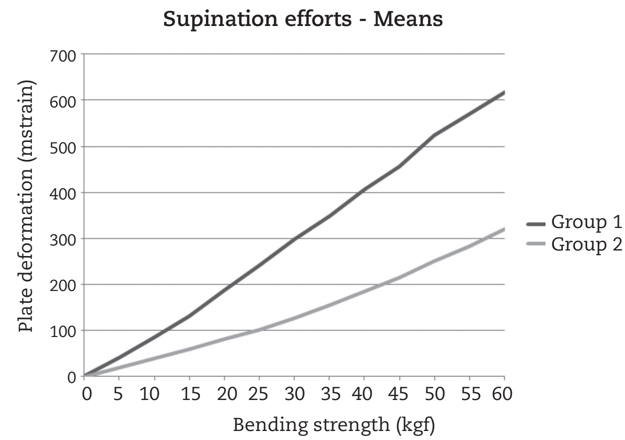


Fig. 9 - The mean of the deformations of Groups 1 and 2 in the first trial, due to the deforming strength (p = 0.25).

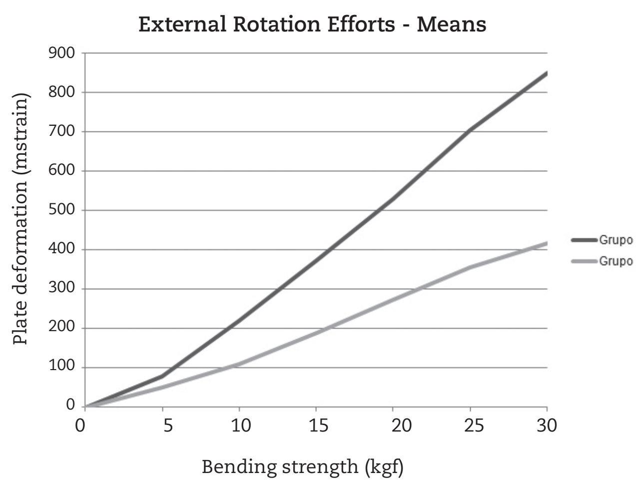


Fig. 10 - The mean of the deformations of Groups 1 and 2 in the first trial, due to the deforming angle (p = 0.04).

For each group, the mean deformation was determined. These results, which are shown in Figs. 9 and 10, were subject to statistical analysis for further interpretation.

By analyzing the graphs, one may notice that the plates in Group 1 (lateral plates) had higher levels of deformity, on average, after being subjected to supination efforts compared to the plates of Group 2 (posterior plate). However, there was no statistical significance (p = 0.25) to this trend. In the trial simulating external rotation efforts, Group 2 was more homogeneous and, on average, suffered from less deformity than the specimens of Group 1. This result was statistically significant (p = 0.04).

Discussion

Various techniques have been described for the surgical treatment of a lateral malleolus fracture. Some authors suggest that the use of plates and screws is the most stable method.[4] Among the plating techniques used for this purpose, two are extensively studied: the lateral and the posterior plate. In a biomechanical study, Schaffer and Manoli[9] submitted cadaver legs to torsional mechanisms to produce a malleolar fracture. The fibulas were then attached with two types of platings and were submitted again to torsional forces. This study revealed greater stability and stiffness of the posterior plate compared to the lateral plate, and this result had statistical significance. This study also demonstrated that failure in the fixation system can be due to synthetic material in more rigid bones or due to release or pulling out of the screws in more fragile and less dense bones. Another study[16] tested the use of fewer screws in the posterior plate and suggested that the plate becomes more stable because all screws are bicortical. However, in the lateral plating, the most distal screws are necessarily unicortical so that they do not stay in an intra-articular position. In addition, the posterior plating requires less deformation of the plate to mold it into the bone.

Some studies use protocols to evaluate the satisfaction of the patient after surgery and to calculate positive and negative results. Tucci Neto et al.[22] noticed a lower rate of postoperative discomfort in patients with posterior plates. Brown et al.[23] reported high rates of pain related to the implant, regardless of the disposition. However, it is known that an implant connected to the lateral cortical leads to prominence of the plate through the skin and may cause higher risks of ischemia or local dehiscence.[16]

The biomechanical studies mentioned above used torsional strength to provoke fractures in cadaveric ankles or simulated them with saws.[9,14] We used synthetic fibulas of exactly the same size and density to homogenize the samples for this trial. Manufactured in Switzerland, these synthetic bones are used in orthopedic workshops and training laboratories. They are made of polyurethane resin, with a trabecular interior simulating spongy bone and rigid external layers that simulate the cortical bone. Tests have demonstrated that synthetic bone fractures are very similar to natural bone fractures when they are subjected to stress, simulating the mechanical properties of human bones.[20]

Our specimens presented failures of 1 mm in the fractures, caused by the saw during the production of the lateral malleolus. This 'bone loss' impaired the anatomical reduction of the failure, as it was located in a non-cylindrical region of the fibula. Despite this inconvenience, most of the specimens were stable when subjected to deforming stress and returned to the initial state of tension when the stress was removed, which suggests that the imperfection of the reduction did not interfere with the results achieved.

The plastic deformation presented by one specimen of each group was due to the incorrect installation of the mandrel that produced the torsional stress over the plates.

The studies applied in this paper did not compare the values obtained in the first trial with the values of the second trial, as the same units were not applied (kilogram-force in the first trial and degrees in the second trial). Furthermore, there is no evidence in the literature that one plating method should protect from supination efforts more than external rotation, or vice-versa. Both randomly occur either separately or in combination in an eventual trauma.

Statistical studies indicate that a greater degree of freedom (greater sample number) could minimize variation in the results obtained, reduce the standard deviation and increase the statistical reliability of the results.[21]

We did not conduct clinical trials, and we cannot infer if there would be satisfaction and/or complications intrinsic to the methods applied. This fact restricted the results to the mechanical analysis of the application methods.

We suggest the use of posterior plate fixation in patients with lower bone density to provide greater stiffness to the plating. We also recommend individually considering the clinical, biological and social features of each case that is presented to the surgeon, in addition to the mechanical factors, when proposing a particular treatment strategy.

Conclusion

Upon consideration of the analysis of our data, we conclude that there is no significant difference between the posterior plates or the lateral plates in the Danis-Weber type-B ankle fractures when subjected to bending strength (simulating supination). When subject to torsional forces (simulating external rotation), the posterior plate has proven to be statistically more rigid than the lateral plate.

Conflict of Interest

The authors declare no conflicts of interest associated with this paper.

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