RESEARCH ARTICLE

Conventional Titanium Acetabular Cups vs. Trabecular Titanium Acetabular Cups in Primary Total Hip Arthroplasty: Ten-year Follow-up Clinical and Radiological Results

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Abstract

Objectives: Evidence supporting the use of trabecular titanium acetabular cups in primary total hip arthroplasty (THA) is generally favorable, especially in the short and mid-term. However, certain considerations remain, and long-term data are still unavailable.

Methods: A total of 53 THAs in 47 patients performed at our institution between 2011 and 2015 were included and divided into two groups to compare clinical and radiological outcomes. Group A included 15 patients with conventional titanium cups, while Group B comprised 38 patients who received trabecular titanium cups.

Results: There were no significant differences between groups regarding demographics, surgical variables, or complication rates. However, patients in Group B were significantly younger and more frequently underwent surgery via a posterolateral approach. Both groups demonstrated significant improvement in Harris Hip Score (HHS) postoperatively ($p < 0.05$), with Group B showing significantly higher final scores ($p < 0.02$). Radiographic cup positioning was similar in both groups. Group B exhibited a higher incidence of initial bone–implant gaps in zone 2, which correlated with higher Body Mass Index ($p = 0.005$) and greater abduction angles ($p = 0.03$). No osteolysis or component migration was observed. One asymptomatic loosening was noted in Group A. No cup revisions were required in either group during the minimum 10-year follow-up.

Conclusion: Both acetabular cup designs achieved excellent long-term clinical and radiological results. In this cohort, tantalum cups were associated with slightly superior functional outcomes, supporting the hypothesis that higher porosity may promote improved biological integration while maintaining implant stability.

Level of evidence: II

Keywords: Conventional, Results, Titanium acetabular cups, Total hip arthroplasty, Trabecular

Introduction

Total hip arthroplasty (THA) is an effective treatment for end-stage hip osteoarthritis.[1,2] Tantalum cups were introduced in hip surgery in 1997. Trabecular metal (Trabecular Metal, Zimmer, Inc, Warsaw, IN, USA) offers 80% porosity, a pore size of 550 µm, a high friction coefficient, and an elastic modulus similar to subchondral bone.[3] These properties promote excellent osseointegration and primary stability in primary hip arthroplasty,[4-6] with favorable outcomes also reported in revision cases, even with limited bone stock.[7-9] The surface roughness, material´s high porosity (75-85%), high coefficient of friction and similar modulus of elasticity to cancellous bone allows enhance shear strength, minimize stress shielding, and reduce implant failure risk.[6]

Advances in technology have improved the porosity, friction, and elastic modulus of titanium cups through various surface coating processes. However, concerns remain regarding the mechanical properties and long-term outcomes of these coatings.

Fully porous titanium structures produced via electron beam technology, have shown promising short-term results in revision surgery.[10] To date, few studies have evaluated trabecular titanium used for primary total hip arthroplasty.[11,12]

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This study aims to compare the clinical and radiographic outcomes of two acetabular cups with identical geometries but differing in material composition and porosity in the context of primary total hip arthroplasty (THA).

Materials and Methods

This study was approved by our Institutional Review Board. We prospectively studied 53 hips implanted in 47 patients at our center between January 2011 and December 2015. The mean age at the time of surgery was 53.1(±14.6) years, with a median Body Mass Index (BMI) of 26.62 (22.0-25.7) kg/m^2.

All patients received the same femoral stem (HMax, Lima, San Daniele, Italy), paired with one of two different acetabular cups. Patients were divided into two groups according to the cup received, in order to compare clinical and radiological outcomes.

In our study, the most common indication for THA was osteoarthritis, observed in 37 patients (76%), followed by avascular necrosis in 7 patients (14%), development hip dysplasia in 5 patients (10%), and one case each of Legg-Calvé-Perthes disease sequelae, rheumatoid arthritis, and idiopathic chondrolysis.

Inclusion criteria for this study were the implantation of a Delta cup at our institution and a minimum follow-up of 10 years. Patients undergoing revision surgery were excluded.

Groups description

All patients received the same femoral stem *(HMax, Lima, San Daniele, Italy),* paired with one of two different acetabular cups, which defined the two groups. The first group (Group A) included 15 patients who received a conventional titanium cup *(Delta PF cup, Lima Corporate),* with a mean age of 59.5 (±10.5) years and a median BMI of 24.4 (21.1-31.9) kg/m^2. A lateral approach in the lateral decubitus position was used in all cases. The most common bearing couple was ceramic-on-ceramic *(Biolox Delta),* used in 10 patients (66%), followed by metal-on-highly cross-linked polyethylene in 5 patients (33%). The median acetabular component size was 52 (50-54) mm. The cup was secured with two screws in all cases (100%).

The second group (Group B) consisted of 38 patients who received a trabecular titanium cup (Delta TT cup, Lima Corporate), with a mean age of 50.9 (±15.3) years and a median BMI of 26.6 (22.8-25.9) kg/m^2. The Hardinge approach was used in 16 patients (42%), while the posterolateral approach was more frequently employed, in 22 patients (58%). Ceramic-on-ceramic was the most common bearing couple, used in 35 patients (92%), followed by metal-on-highly cross-linked polyethylene in 3 patients (8%). The median acetabular component size was 50 (50-52) mm. The cup was secured with two screws in 36 cases (95%). Patient data and surgical data are shown in [Table 1].

Table 1. Demographic characteristics and surgical outcomes

	Group A (n = 15)	Group B (n = 38)
Gender		
Male	7	23
Female	8	15
Age (years) (*)	59.5 ± 10.5	50.7 ± 15.3
BMI (kg/m2) (**)	24.4 (21.1 – 31.9)	26.6 (22.8 – 25.9)
Side of surgery		
Right	7	18
Left	8	20
Diagnosis		
Ostheoartritis	13	23
AVN	1	6
Hip dysplasia	1	4
Legg-Calvé- Perthes disease	0	1
Others	0	4
Cup size		
44 mm	0	1
46 mm	0	3
48 mm	3	4
50 mm	1	10
52 mm	4	12
54 mm	4	3
56 mm	3	4
60 mm	0	1
Femoral head size		

Table 1. Continued		
28 mm	1	1
32 mm	6	10
36 mm	6	27
40 mm	2	0
Neck length		
Small	2	4
Medium	9	27
Large	4	7
Bearing couple		
Ceramic-on-ceramic	10	35
Metal-on-highly cross-linked polyethylene	5	3
Use of screws (2)		
Yes	15	36
No	0	2
Surgical approach		
Hardinge	15	16
Posterolateral	0	22
Hemoglobin levels (g/dl) (**)		
Preoperative	15.4 (14.3 – 16.1)	14.9 (14.0 – 15.6)
After surgery	10.9 (10.0 – 12.8)	12.2 (10.6 – 12.8)
Need for blood transfusion		
Yes	0	1
No	15	37

(* Data are expressed as median and standard deviation (SD))
(** Data are expressed as median and interquartile range (IQR))

Both cups share the same design: they are hemispherical, with an identical screw hole pattern and liner locking mechanism. Their only difference lies in their composition. The Delta PF cup *(Lima, San Daniele, Italy)* is a conventional titanium cup with a hydroxyapatite coating, offering approximately 20% porosity. In contrast, the Delta TT cup *(Lima, San Daniele, Italy)* consists of a three-dimensional titanium structure without any coating, providing a porosity of 65% or higher [Figure 1].

Figure 1. Tridimensional structure of the Delta TT cup (Images from Lima, San Daniele, IT)

Surgical Procedure and Postoperative Management

All prostheses were implanted under spinal anesthesia. Hardinge and the posterolateral approaches were used, depending on the surgeon's preference.[13] The acetabulum was reamed line-to-line, and the cup used was 1.2 mm oversized relative to last reamer. The median acetabular component size was 52 (50-54) mm. In 96% of cases, cups were secured with two additional screws. A ceramic-on-ceramic bearing was used in 45 hips, and a metal-on-highly cross-linked polyethylene bearing in 8 hips.

Thromboprophylaxis with low-molecular-weight heparin was prescribed for 4 weeks. All patients received perioperative antibiotic prophylaxis with a second-generation cephalosporin, or vancomycin in cases of allergy. Post-operatively, all patients received 48 hours of antibiotic prophylaxis (1g of cefazolin) and 4 weeks of low-molecular-weight heparin subcutaneously for thromboembolic prevention.

Partial weight bearing with crutches was permitted in all cases starting on the second postoperative day until 4 weeks after surgery and followed by full weight-bearing for the following 6 weeks with one crutch in most cases.

Two patients (one from each group) died during the follow-up period, and four were lost to follow-up (one from group A and three from group B).

Clinical and Radiological Evaluation

Patients were assessed clinically and radiologically immediately after surgery, at 6 weeks, 3 months, 6 months, 1 year, and annually thereafter. Clinical evaluation was performed using the Harris Hip Score (HHS), both preoperatively and postoperatively; [14] in the most recent follow-up, patients were also assessed using the Hip disability and Osteoarthritis Outcome Score (HOOS).[15] Standard anteroposterior (AP) and lateral radiographs of the pelvis and the operated femur were obtained at each follow-up visit. Variations in magnification were corrected using the known diameter of the femoral head as an internal reference.

Cup position was determined with the acetabular abduction angle, the horizontal distance measured from the center of the femoral head to Köhler's line, and the vertical distance from the center of the femoral head to the inter-teardrop line. Acetabular reconstruction of the center of rotation of the hip was defined according to the criteria of Ranawat et al.[16] Radiographs were examined for the presence of radiolucent lines, sclerotic lines, or gaps on the initial postoperative images, and for osteolytic lesions during follow-up. When present, these findings were classified according to their location using the zones described by DeLee and Charnley.[17] Osseointegration and migration was also assessed according to Moore's criteria.[18]

Statistical Analysis

Categorical variables were expressed as counts and percentages, and quantitative variables as mean ± standard deviation, or median [interquartile range], based on their distribution. Group comparisons for categorical variables were conducted using the chi-squared test or the Fischer's exact test as appropriate, while the Wilcoxon rank-sum test was performed as a non-parametric test for quantitative variables, given the overall sample size. A p-value <0.05 was considered statistically significant and all the analyses were performed in Stata BE 18.0 (StataCorp).

Results

There were no significant differences between groups in terms of gender distribution, BMI, side of surgery, diagnosis, cup size, femoral head or neck size, bearing couple, use of screws, changes in hemoglobin levels, need for blood transfusions, complications during or after surgery, or length of follow-up. Significant differences were observed in age and surgical approach between the two groups. These data are represented in [Table 1].

Two intraoperative calcar fractures occurred, both managed with cerclage wiring, without compromising stem stability. Postoperatively, one case of pulmonary thromboembolism was recorded two months after surgery, and one case of common peroneal nerve palsy was observed immediately after surgery, which resolved without sequelae.

No acetabular component required revision surgery due to any reason. Two patients (one from each group) died during the follow-up period, and four were lost to follow-up (one from group A and three from group B).

Harris Hip Score improved in both groups from the pre-operative value to the latest follow-up ($p < 0.05$). The median preoperative HHS was 27.0 (27.0-27.0 in Group A which improved to 90.4 (82.7-95.8) after 10 years of follow-up. In Group B, the median HHS improved from 44 to 96.0 (90.0-97.8) at final follow-up. A significant difference was observed at final follow-up ($p < 0.02$). At latest follow-up, patients were also evaluated using the HOOS. Group A showed a median score of 88.0 (82.0-89.0), while Group B had a median score of 91.0 (87.5-94.0) ($p = 0.02$).

Postoperative hip reconstruction improved significantly in both groups for all measurements, including acetabular abduction angle, horizontal and vertical distances and center of rotation restoration ($p < 0.01$) [Table 2].

Immediately after surgery, a lack of contact between the cup and bone in zone 2 was observed in some patients. Bone–implant gaps were identified in 2 cases in Group A and 8 cases in Group B ($p = 0.48$). All of these radiolucent lines resolved within the first year postoperatively, with no progression observed during follow-up and no associated clinical impact [Figure 2].

A statistically significant association was observed between BMI and the presence of initial bone–implant gaps ($p = 0.005$). Patients without gaps had a lower median BMI [24.7 kg/m^2 (Interquartile range-IQR: 21.9–29.1)] compared to those with gaps [32.5 kg/m^2 (IQR: 26.6–33.4)].

Additionally, the presence of gaps was significantly correlated with cup abduction angle ($p = 0.03$). Gaps were more frequently observed in implants positioned at higher abduction angles, with a median of 48.5° (IQR: 46.0–51.0) versus 44.0° (IQR: 39.5–47.5) in implants without gaps.

Table 2 (a-b). Radiographic results

	Cup abduction	Horizontal distance (mm)	Vertical distance (mm)	Distance to CR (mm)
(a) Immediate postoperative period				
Group A	*44.9º (38.0-47.0)*	*31.0 (28.0-37.0)*	*18.0 (15.0-25.0)*	*4.0 (2.5-6.0)*
Group B	*45.0º (41.0-49.0)*	*31.0 (29.0-33.0)*	*15.0 (11.0-17.0)*	*3.0 (2.0-6.0)*
(b) Ten years follow-up. Data are expressed as median and interquartile range (IQR)				
	Cup abduction	**Horizontal distance (mm)**	**Vertical distance (mm)**	**Distance to CR (mm)**
Group A	44.5º (40.4-52.0)	30.3 (25.2-34.8)	15.8 (13.0-23.5)	3.45 (2.6-6.5)
Group B	46.0º (41.5-48.0)	30.6 (25.1-35.0)	15.0 (12.0-17.2)	3.0 (2.0-4.0)

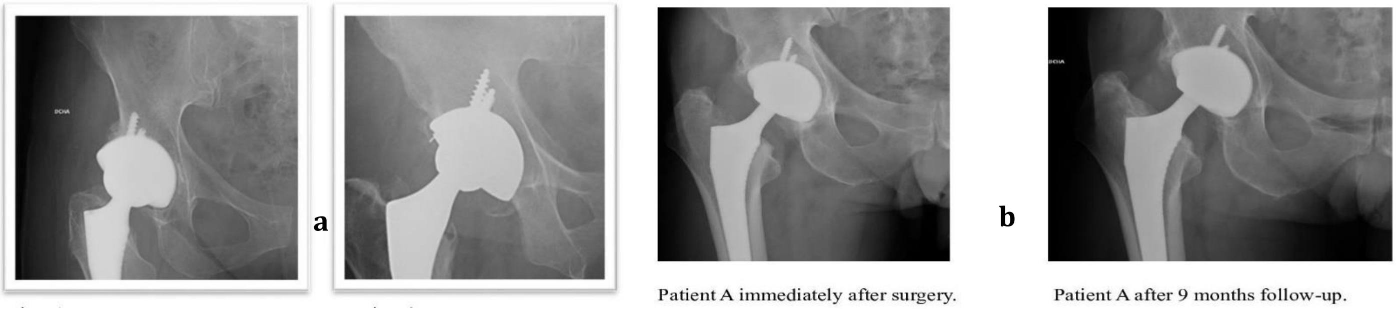

Figure 2 (a-b). (a) Hip anteroposterior (AP) x-rays showing lack of contact between cup and bone in zone 2 immediately after surgery. (b) Hip AP x-rays showing progressive filling of the gap between the implant and the bone during patient follow-up

No significant association was found between cup size and the presence of gaps (p = 0.35) [Figure 3].

Only one cup in Group A was loose. The patient reported only mild symptoms, experienced no physical limitations, and surgery was not indicated. Five cups in Group B showed radiolucent lines, all located in zone 3. Additionally, one cup in Group B showed a sclerotic line in zone 1. All those lines were under two millimeters and were non-progressive. No osteolytic lesions were observed in any patient. There was no problem related to incomplete setting, chipping of the ceramic liners in this series. No need for revision surgery was registered in any cases during the follow-up 12.18 (10.7-13.1) years.

Discussion

Trabecular metal is primarily used in revision surgery due to its excellent primary stability and highly porous structure, which promotes bone integration in cases with limited bone stock.[7-9] However, excellent long-term survivorship has also been reported in primary THA.[5,19] Comparative studies between tantalum and conventional titanium cups have shown comparable clinical and radiological outcomes.[20]

Trabecular titanium provides a similarly porous structure, which supports its use in revision surgery.[10] To our knowledge, few studies have evaluated this type of cup in primary THA, with reported survivorship rates of up to 99.3% at 5-year follow-up.[11] As emphasized by Malahias, studies assessing long-term outcomes are expected to provide further insights into the subject.[21] We obtained excellent clinical and radiological outcomes in both groups, with high implant survivorship at mid-term follow-up. No significant clinical or statistical differences were observed between the two acetabular cup models based on the parameters studied.

We observed reduced immediate postoperative contact between the cup and bone when using trabecular titanium implants, possibly due to increased grip of the implant at the acetabular rim during insertion. Its higher incidence in patients with higher BMI and vertical positioned implants may be due to the challenges in obtaining proper placement and impaction in patients with severe obesity. This phenomenon had no clinical significance and resolved in most cases during follow-up. Similarly, pure tantalum monoblock cups have demonstrated dome gaps in 16–24% of cases, which fully resolve after osseointegration, typically within 24 weeks.[22] Nevertheless, the Delta cup is hemispherical, whereas the tantalum cup has a hemiellipsoid shape, with a dome diameter that is 2 mm smaller than its equator diameter.[4,6]

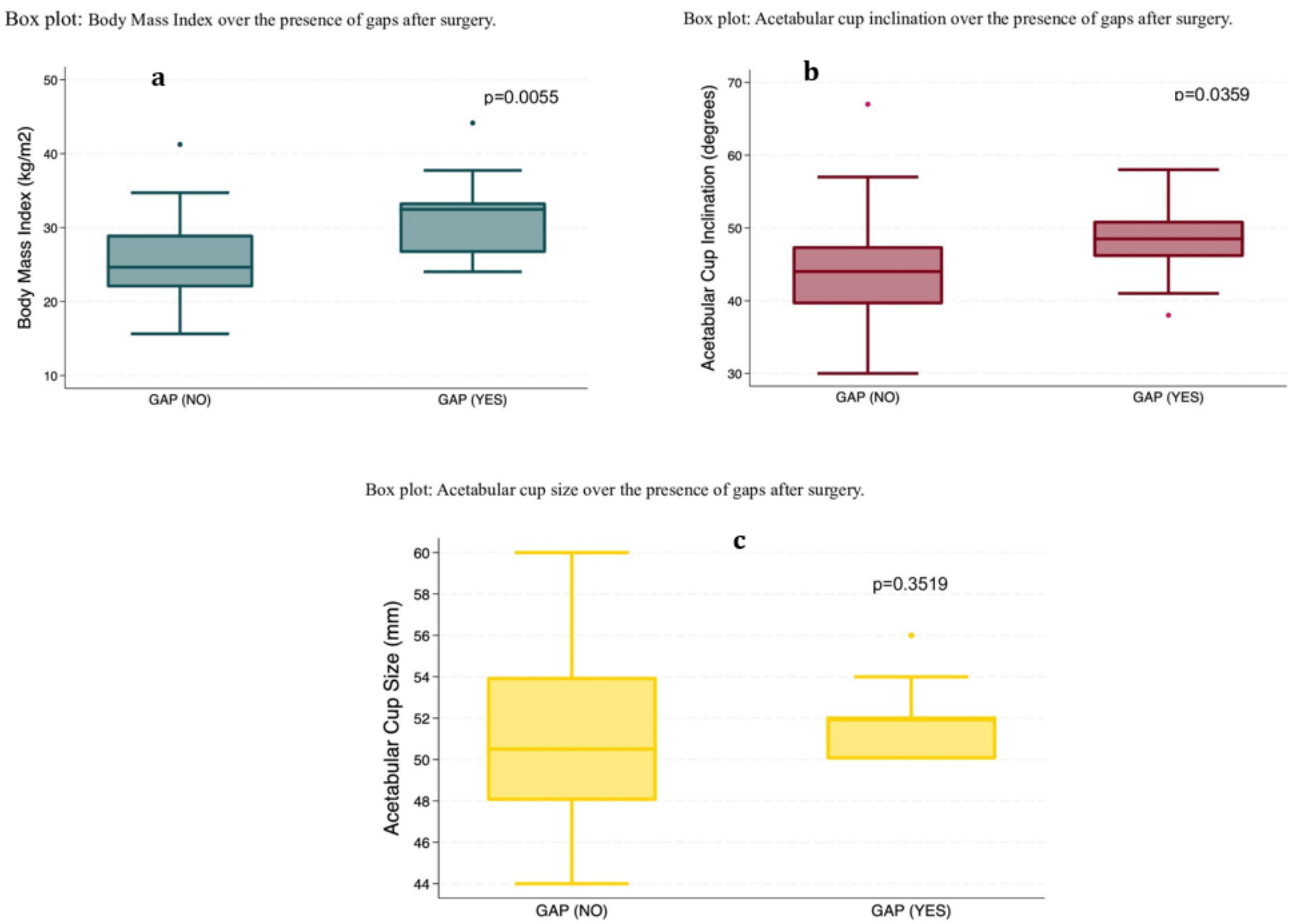

Figure 3 (a-c). Box plots: (a) Body Mass Index over the presence of gaps after surgery. (b) Acetabular cup inclination over the presence of gaps after surgery. (c) Acetabular cup size over the presence of gaps after surgery

Initial primary stability is essential to achieve bone ingrowth, as early component migration can predict an increased risk of revision surgery due to aseptic loosening.[23,24] The presence of progressive radiolucent lines is a predictor of poor implant integration; however, their incidence has decreased with contemporary cup designs.[25,26] Ultraporous materials have been developed to enhance fixation by providing increased porosity and friction coefficient. The osseointegration of trabecular metal implants has been evaluated using dual-energy X-ray absorptiometry (DXA), demonstrating favorable outcomes.[6] Although no clinical differences were observed between groups in our study, cups presenting radiolucent lines exhibited lower HHS compared to those with complete integration, albeit without statistical significance.

Perticarini et al. reported trabecular titanium cups as an excellent option for both high-demand and elderly patients, with ceramic-on-polyethylene as their preferred bearing surface.[9] In our study, the most common bearing couple was ceramic-on-ceramic. Although liner canting dissociation—which raises concerns about ceramic fracture—has been reported, no such complications were observed in our series.[27] The ceramic liner design, featuring a polar peg, facilitates proper insertion and minimizes the risk of incomplete seating or positioning in a canted orientation. Consequently, no cases of chipping or fracture of ceramic liners were observed in our series.

Several designs have introduced various ultraporous materials to enhance fixation. However, concerns regarding osseointegration of certain implants with highly porous coatings have been investigated. The risk of surface damage and coating debonding may compromise cup integration and long-term survivorship.[21] Registry data suggest higher revision rates for trabecular metal acetabular cups used in primary surgery compared to conventional acetabular designs. Trabecular titanium implants are manufactured as a three-dimensional porous structure rather than a surface coating. This design minimizes the risk of surface damage or debonding during follow-up.[11]

Limitations of the study: This is an observational study with a relatively small sample size. It is not randomized, and the choice of acetabular cup was based on surgeon preference. Multiple surgeons participated, which may introduce bias. Additionally, patients in Group B were significantly younger and more frequently operated on using a posterolateral approach. Results may evolve as the follow-up period is extended and the sample size increases. Both acetabular cup designs demonstrated excellent long-term clinical and radiological outcomes. In this cohort, tantalum cups were associated with slightly superior functional outcomes, supporting the hypothesis that higher porosity may promote improved biological integration while maintaining implant stability.

Our study confirms the results published in 2022 by Rambani et al. In a review of the literature they stated that tantalum was superior to titanium with regards to fewer radiolucencies, 100% survivorship at 12 years postoperatively, improved long-run implant osteointegration and survivorship as well as decreasing osteolysis and mechanical loosening. There was no substantial difference in radioisometric analysis, bone mineral density or HHS. Revision and infection rates were encountered to be substantially lower in tantalum group at 10 years from pooled data of national joint registry (England and Wales), while it was encountered to be higher in the same at 9 years from pooled data of Swedish and Australian registry although this was not statistically significant.[28]

Conclusion

In conclusion, both acetabular cup designs accomplished excellent long-run clinical and radiological outcomes. In this cohort, tantalum cups were associated with slightly superior functional results, supporting the hypothesis that higher porosity might promote improved biological integration while maintaining implant stability.

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