Short-Term Outcomes of the Grammont Reverse Shoulder Arthroplasty: Comparison between First and Second Generation Delta Prosthesis

Riccardo Luigi Alberio1, Marco Landrino1, Paolo Fornara1, Federico Alberto Grassi1

1 Department of Orthopaedics and Traumatology, University of East Piedmont, Hospital “Maggiore della Carità,” Novara, Italy

Address for correspondence Riccardo Luigi Alberio, MD, Department of Orthopaedics and Traumatology, University of East Piedmont, Hospital “Maggiore della Carità,” Corso Mazzini, 18-28100 Novara, Italy (e-mail: riccardo.alberio@gmail.com).

Abstract

Purpose This article compares short-term outcomes of two series of patients, who underwent reverse total shoulder arthroplasty (RTSA) with two different implants, both based on Grammont’s principles: the Delta III (D-3) and the Delta Xtend (D-XT) prostheses.

Methods The D-3 group included a consecutive series of 26 patients (mean age 75 years), that were treated between 2000 and 2006; the D-XT group included a consecutive series of 31 patients (mean age 72.5 years), for a total of 33 implants performed between 2011 and 2015. In both groups the most common diagnoses were cuff tear arthropathy (18 and 22 shoulders, respectively) and malunion of proximal humerus fractures (3 and 5). All procedures were performed by the same surgeon. Constant–Murley score (CMS) was used to assess clinical and functional outcomes. Radiographic evaluation included the true anteroposterior and axillary views.

Results Twenty-three patients of the D-3 group and 22 patients (24 shoulders) of the D-XT group were evaluated at a mean follow-up of 42 months (range 26–84) and 44 months (range 26–66), respectively. Four complications occurred in the D-3 group (1 partial deltoid detachment, 1 dislocation, and 2 glenoid component loosening), while one early postoperative infection occurred in the D-XT group. Increases in elevation and CMS between preoperative and postoperative period were observed in both groups; only the D-XT group showed a slight improvement in rotations. The incidence of scapular notching was significantly different between the two groups: 100% for D-3 and 22.2% for D-XT in patients with a minimum follow-up of 5 years.

Conclusion Prosthetic design evolution and greater acquaintance with this surgery have undoubtedly led to an improvement in short-term outcomes with second generation implants of RTSA. Future studies will have to ascertain whether newer implants, relying on biomechanical solutions alternative to Grammont’s original concept, might provide additional advantages and minimize drawbacks.
Introduction

Grammont reverse total shoulder arthroplasty (RTSA) was a revolutionary solution for the surgical management of cuff tear arthropathy\(^1\) and other difficult shoulder conditions, such as fracture sequelae of proximal humerus and failed prostheses.\(^2\) RTSA has also shown to be effective for the treatment of proximal humeral fractures, particularly in elderly patients or in cuff-deficient shoulders.\(^3\)–\(^7\) During the last decade, the worldwide use of RTSA as well as the scientific literature related to this topic have steadily increased and several prosthetic models have been introduced on the market.

The reverse prosthesis aims to provide a fixed fulcrum for deltoid action in case of cuff failure. The original Delta design, developed by Paul Grammont in the eighties, was characterized by the medialization of the center of rotation and the 155-degree inclination of the humeral component. These features allowed to decrease shear and bending stresses at the scapular bone-prosthesis interface, and achieve joint stability by deltoid coaptation.

However, the earlier clinical experiences highlighted some biomechanical drawbacks of RTSA as well as a high incidence of complications, such as infections and instability.\(^8\)–\(^10\) Scapular notching was the main reason for concern, because it could be responsible for progressive bone loss of the scapular neck and subsequent loosening of the glenoid component, a condition with limited treatment options.

The second generation Delta prosthesis introduced some innovations to overcome this problem, but the implant still relied on Grammont medialization concept. The new design included a smaller baseplate and eccentric glenospheres to facilitate lowering of the glenoid component.\(^11\)–\(^13\) Less congruent humeral inserts were introduced for preventing polyethylene wear while improving range of motion (ROM).\(^14\) Curved back baseplate and thinner humeral epiphysis aimed to preserve glenoid and humeral bone stock, respectively.

The purpose of this study is to present a retrospective evaluation of a single-surgeon experience with RTSA, by analyzing and comparing the short-term clinical and radiographic results achieved in two series of patients treated with the Grammont RTSA in two different time periods. The earliest series included patients treated with the first generation Delta prosthesis between 2000 and 2006, while the second series included patients treated with the second generation Delta prosthesis between 2011 and 2015.

We hypothesize that technological and surgical advances in RTSA resulted in better clinical outcomes and lower complication rates.

Methods

This retrospective study was performed on two group of patients, that underwent RTSA in two different time periods. All patients were affected by nontraumatic problems of the shoulder and had a minimum follow-up of 2 years.

The first group included a consecutive series of 26 patients (24 women, 2 men) that were treated from October 2000 to June 2006 with the Delta III prosthesis (DePuy International, Leeds, United Kingdom) (group D-3); mean age was 75 years (range, 62–84).

The second group included a consecutive series of 31 patients (28 women, 3 men) that were treated from February 2011 to March 2015 with the Delta Xtend prosthesis (DePuy International) (group D-XT); mean age was 72.5 years (range, 59–79). Two patients were treated bilaterally, for a total of 33 implants.

Preoperative clinical data of the two groups of patients are reported in Table 1.

All the surgical procedures were performed by the same surgeon. The transdeltoid approach was used in 15 patients of group D-3, while the deltopectoral approach was used in all the remaining patients. In group D-XT, the subscapularis tendon was never repaired at the end of the procedure.

The humeral component was cemented in 17 cases (65.4%) of group D-3 and in 10 cases (30.3%) of group D-XT. Retroversion of the humeral component varied among patients of group D-3: 0 degrees in 6 cases, 5 degrees in 1, 10 degrees in 4, 15 degrees in 6 cases, 20 degrees in 6 cases, 25 degrees in 3 cases, and 30 degrees in 3 cases.

The purpose of this study is to present a retrospective evaluation of a single-surgeon experience with RTSA, by analyzing and comparing the short-term clinical and radiographic results achieved in two series of patients treated with the Grammont RTSA in two different time periods. The earliest series included patients treated with the first generation Delta prosthesis between 2000 and 2006, while the second series included patients treated with the second generation Delta prosthesis between 2011 and 2015.

We hypothesize that technological and surgical advances in RTSA resulted in better clinical outcomes and lower complication rates.


table

<table>
<thead>
<tr>
<th>Group D-3</th>
<th>Group D-XT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>26 (24 ♀, 2 ♂)</td>
</tr>
<tr>
<td>Implants (n)</td>
<td>26</td>
</tr>
<tr>
<td>Age (y)</td>
<td>75 (62–84)</td>
</tr>
<tr>
<td>Follow-up (mo)</td>
<td>42 (26–84)</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>CTA</td>
<td>18</td>
</tr>
<tr>
<td>Malunion</td>
<td>3</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>1</td>
</tr>
<tr>
<td>Glenohumeral instability</td>
<td>1</td>
</tr>
<tr>
<td>Old unreduced dislocation</td>
<td>–</td>
</tr>
<tr>
<td>AVN humeral head</td>
<td>–</td>
</tr>
<tr>
<td>Failed hemiarthroplasty</td>
<td>3</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>8</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>2</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>2</td>
</tr>
<tr>
<td>Hypothyroidism</td>
<td>–</td>
</tr>
<tr>
<td>Benign prostatic hyperplasia</td>
<td>1</td>
</tr>
<tr>
<td>Gout</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviations: AVN, avascular necrosis; CTA, cuff tear arthropathy.
10 degrees in 16, and 20 degrees in 3 cases. In group D-XT, the humeral component was always implanted in 20 degrees of retroversion.

Rehabilitation protocol was influenced by the surgical approach. Active elevation of the shoulder in the scapular plane was immediately allowed after the deltopectoral approach, but it was delayed for 4 weeks after the transdeltoid approach since the deltoid was partially detached from the acromion. Assisted passive elevation was started in all patients on the first postoperative day.

Clinical evaluation with the Constant–Murley score (CMS)\(^\text{15}\) was performed preoperatively and at follow-up. The normalized CMS score was expressed as a percentage of premeasured normal values, matched for age and sex.\(^\text{16}\) Active ROM for anterior elevation, external, and internal rotation was also assessed.

After surgery, patients were recalled at intervals of 3, 6, and 12 months and yearly thereafter for radiographic evaluation in two orthogonal views (true anteroposterior and axillary).

Scapular notching was assessed according to the Nerot classification.\(^\text{17}\) The presence of radiolucent lines around the humeral component, osteophytes, and heterotopic ossifications was also investigated. Radiolucent lines around the humeral component were classified according to their width \((\leq 2 \text{ or } > 2 \text{ mm})\) and zones involved, as described by Sanchez-Sotelo et al.\(^\text{18,19}\)

Statistical analysis was performed to compare mean variations in ROM and Constant scores from baseline to follow-up between the two groups: \(p\) was obtained by comparing follow-up data using baseline score as covariate with an analysis of covariance model.

The difference in scapular notching incidence between the two groups was compared using the Fisher’s exact test.

A \(p\)-value of \(< 0.05\) was considered statistically significant.

**Results**

Twenty-three patients (88.4\%) of group D-3 were available at an average follow-up of 42 months (range, 26–84); one patient died of lung cancer and two patients could not be evaluated due to debilitating neurological conditions unrelated to their surgery. Twenty-two patients, for a total of 24 implants (72.7\%), of group D-XT were evaluated at an average follow-up of 42 months (range, 26–86); three patients died from causes unrelated to the surgical procedure, three were unable to reach our institution for geographical distance, two from causes unrelated to the surgical procedure, three were unable to reach our institution for geographical distance, and one patient was untraceable.

Two early postoperative complications were observed in group D-3: one partial detachment of the lateral deltoid after transdeltoid approach, that was treated conservatively and healed uneventfully, and one dislocation, that was promptly reduced and did not recur. An early deep infection occurred in one patient of group D-XT 2 weeks after surgery: it was treated with debridement, glenosphere, and humeral insert replacement and 6-week targeted antibiotic therapy. At 4-year follow-up, there were no clinical signs of infection and laboratory tests (erythrocyte sedimentation rate, polymerase chain reaction) were negative, but the patient complained of recurrent shoulder discomfort and radiograms showed progressive humeral radiolucency combined with scapular notching (►Fig. 1).

Two cases of glenoid component loosening, respectively at 6 months and 5 years, occurred in group D-3: both patients underwent revision surgery. In the first one, the glenoid component was replaced using a special metaglene with a plate for additional screw fixation and cancellous bone graft to fill the bone defect at the scapular neck. The second patient was treated with conversion to a hemiarthroplasty owing to the extensive bone loss and low functional demands. No late complications were observed in group D-XT.

Mean ROM and CMS of the two groups recorded preoperatively and at follow-up are shown in ►Table 2. The comparison of ROM changes from baseline to follow-up between the two groups did not show any significant difference (►Table 3). Despite the greater improvement in rotations observed in the D-XT group, significance was not reached due to the differences in baseline values.

Average absolute CMS value increased by 32.4 points \((\pm 11.9)\) in the D-3 group and 38.3 points \((\pm 10.0)\) in the D-XT group. The between-group difference was statistically significant \((p = 0.007)\). Also for the normalized CMS, the difference of 7.1 percentage points between the two groups was significant \((p = 0.012)\) (►Table 3). The most relevant disparities between the two implants were noticed in radiographic findings.

Incidence, severity, and trend to progression of the scapular notch were higher in group D-3, as shown in ►Table 4. Differences in incidence were found to be statistically significant every year during follow-up. Among patients who were

![Fig. 1](image-url)
followed up for 5 years, the incidence of scapular notching was 100% (10/10) for group D-3 and 22.2% (2/9) for group D-XT. Moreover, Nerot grades 3 and 4 were only observed in 5 patients of group D-3 (► Fig. 2).

Humeral radiolucencies ≥ 2 mm were observed in three patients of group D-3 and in one of group D-XT. All the components were uncemented and only metaphyseal zones were involved (zones 1 and 7). In group D-3, radiolucencies came into view 5 years after surgery and were always associated with scapular notching (grade 2 or higher). In group D-XT, there was only one case of progressive humeral radiolucency combined with grade 1 scapular notching; this

Table 2 Mean ROM and CMS recorded in the preoperative period and at follow-up in the two groups

<table>
<thead>
<tr>
<th></th>
<th>Group D-3</th>
<th></th>
<th>Group D-XT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 23</td>
<td></td>
<td>n = 24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preop</td>
<td>Follow-up</td>
<td>Preop</td>
<td>Follow-up</td>
</tr>
<tr>
<td>Forward elevation</td>
<td>66.1 (± 28.2)</td>
<td>132.6 (± 26.7)</td>
<td>63.1 (± 33.9)</td>
<td>140.6 (± 21.1)</td>
</tr>
<tr>
<td>External rotation</td>
<td>17.0 (± 13.4)</td>
<td>15.4 (± 10.5)</td>
<td>8.1 (± 19.1)</td>
<td>20.8 (± 11.8)</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>L3</td>
<td>L4</td>
<td>Sacrum → L4</td>
<td>28.2 (± 6.8)</td>
</tr>
<tr>
<td>Absolute CMS</td>
<td>23.2 (± 9.8)</td>
<td>55.6 (± 9.2)</td>
<td>26.4 (± 7.8)</td>
<td>64.7 (± 10.7)</td>
</tr>
<tr>
<td>Pain</td>
<td>3.9 (± 3.0)</td>
<td>12.4 (± 3.0)</td>
<td>2.5 (± 2.9)</td>
<td>12.7 (± 3.6)</td>
</tr>
<tr>
<td>ADL</td>
<td>8.6 (± 3.5)</td>
<td>15.0 (± 2.9)</td>
<td>9.6 (± 2.9)</td>
<td>18.5 (± 2.2)</td>
</tr>
<tr>
<td>ROM</td>
<td>10.1 (± 5.2)</td>
<td>25.1 (± 5.5)</td>
<td>12.5 (± 6.2)</td>
<td>28.2 (± 6.8)</td>
</tr>
<tr>
<td>Strength</td>
<td>0.7 (± 0.9)</td>
<td>3.1 (± 1.4)</td>
<td>1.8 (± 2.3)</td>
<td>5.3 (± 2.9)</td>
</tr>
<tr>
<td>Normalized CMS</td>
<td>29.0% (± 12.3%)</td>
<td>69.6% (± 12.0%)</td>
<td>32.8% (± 9.6%)</td>
<td>80.5% (± 13.5%)</td>
</tr>
</tbody>
</table>

Table 3 Comparison of differences in ROM and CMS from preoperative period to follow-up between the two groups

<table>
<thead>
<tr>
<th></th>
<th>Group D-3</th>
<th></th>
<th>Group D-XT</th>
<th></th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 23</td>
<td></td>
<td>n = 24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward elevation</td>
<td>+66.5° (± 29 + 5°)</td>
<td>+77.5° (± 28.8°)</td>
<td>0.154</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External rotation</td>
<td>−1.6° (± 14.6°)</td>
<td>+12.7° (± 21.2°)</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal rotation</td>
<td>L3 → L4</td>
<td>Sacrum → L4</td>
<td>0.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute CMS</td>
<td>+32.4 (± 11.9)</td>
<td>+38.3 (± 10.0)</td>
<td>0.007a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>+8.5 (± 4.1)</td>
<td>+10.2 (± 5.2)</td>
<td>0.897</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADL</td>
<td>+6.4 (± 3.5)</td>
<td>+8.9 (± 3.8)</td>
<td>&lt; 0.001a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROM</td>
<td>+15.0 (± 6.8)</td>
<td>+15.7 (± 4.9)</td>
<td>0.295</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength</td>
<td>+2.4 (± 1.4)</td>
<td>+3.5 (± 2.9)</td>
<td>0.014a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalized CMS</td>
<td>+40.5% (± 15.1%)</td>
<td>+48.9% (± 13.2%)</td>
<td>0.012a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Comparison of incidence and severity of scapular notching during the study period between the two groups

<table>
<thead>
<tr>
<th></th>
<th>Group D-3</th>
<th></th>
<th>Group D-XT</th>
<th></th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>F/U</td>
<td>n</td>
<td>Incidence</td>
<td>Nerot gradea</td>
</tr>
<tr>
<td>Nerot gradea</td>
<td>Incidence</td>
<td>n</td>
<td>Incidence</td>
<td>n</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>43.5%</td>
<td>23 1 year</td>
<td>24</td>
<td>8.5%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>69.5%</td>
<td>23 2 years</td>
<td>24</td>
<td>12.5%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>88.9%</td>
<td>18 3 years</td>
<td>20</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>92.3%</td>
<td>13 4 years</td>
<td>13</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>10 5 years</td>
<td>9</td>
<td>22.2%</td>
<td></td>
</tr>
</tbody>
</table>

aShades of gray indicate different severity of the Nerot scale (light gray = grade 1, dark gray = grade 4).
follow-up (Fig. 1). A large amount of research has been devoted to this topic, probably the most debated in RTSA. In previous clinical studies, reported rates of reconstruction of the subscapularis were significantly lower in the first generation Delta prosthesis. This might be related to the different retroversion of the humeral component chosen in the two series of patients. According to Grammont’s indication, most of the Delta 3 prostheses were implanted between 0 and 10 degrees of retroversion. Conversely, a 20-degree retroversion angle was adopted for all the humeral components of the Delta Xtend. This different orientation was probably useful for gaining external rotation and did not have any repercussion on internal rotation.

It has been reported that integrity of teres minor is a critical factor for the recovery of external rotation after RTSA, but we do not have sufficient data—namely magnetic resonance imaging findings—to assert that this factor influenced the ROM differences between the two groups of patients.

The role of the subscapularis in hindering external rotation is still debated, but its repair in undue tension, particularly with the deltopectoral approach and lateralized RTSA, should be avoided. In our experience, the subscapularis was never repaired in the patients treated more recently and this choice might have contributed to improve recovery of external rotation. At the same time, the absence of the subscapularis did not impair either internal rotation or implant stability, since no dislocation occurred in group D-XT.

Finally, the availability and the more extensive use of less congruent humeral inserts and larger glenospheres are implant-related factors that potentially played a role in achieving wider ROM with the second generation prosthesis.

The increase in CMS from baseline to follow-up was significantly greater for the D-XT group, but the improvements achieved in both groups are in accordance with the data reported in the main clinical series found in literature. Our analysis showed that clinical results might be improved by newer RTSA designs, even though we could not demonstrate significant differences in ROM changes in the comparison between the two groups. The complication rate was higher in the earlier series of patients: 18.2% versus 4.2%. This trend is mainly influenced by the learning curve of RTSA and the refinement in surgical technique and patient selection, as reported by other authors. However, loosening of the glenoid component occurred exclusively in two patients with the Delta 3 prosthesis. The absence of mechanical failures in group D-XT leads us to suppose that inherent features of second generation implants also played a role in decreasing the complication rate.

Radiographic analysis showed a significant difference in the incidence of scapular notching between the two series of patients throughout the whole study period. A large amount of research has been devoted to this topic, probably the most debated in RTSA.
of scapular notching in the short-term ranged from 10 to
96%.2,22–27,35,39,40

Osteolysis at the scapular neck can derive either from
impingement of the medial border of the humeral implant
against the inferior rim of the glenoid or as a result of an
inflammatory response to polyethylene debris. The former
mechanism is thought to be responsible for low-grade not-
ing and the latter for high-grade notching with severe bone
loss, eventually involving the proximal humerus.22,26,27,39

Several factors can influence ROM and impingement in
RTSA, contributing to onset and progression of scapular
notching. Patient-related factors include body mass index,
scapular neck angle, scapular neck length, and individual
biological reactivity to implant debris.11,23,26,27,41,42 Some
factors related to the surgical technique are critical: gleno-
sphere height and tilt above all, but also the version angles
of the components.11,23,24,26,27,34,40–43 Finally, implant design
features such as the position of the center of rotation,
glenosphere size and overhang, humeral neck angle, and
humeral implant constraint play a role.34,44,45 Efforts by sur-
geons and manufacturing companies have been addressed to
improve surgical techniques and implant designs with the
aim to decrease the rate of scapular notching.23,24,34,40

The effect of scapular notching on clinical outcome is
discussed in various studies.22,35,46,48 but others pointed out that severe scapular erosions might be
totally asymptomatic.22,25,26,28,39,49 In this study, we could
not find a correlation between notching and poorer clinical
outcomes in both series of patients.

An even more important issue is the potential progression
of scapular notching with time.20,26,27,39 Our experience
shows that the incidence of scapular notching with the first
generation prosthesis (100%) was five times higher than that
of the second generation implant (22.2%) at the 5-year
follow-up. Moreover, the severity of notching was also
greater in the earlier series of patients and caused loosening
of two glenoid components.

There are some limitations of this study that temper our
analysis and results interpretation, such as the retrospective
design and the short-term follow-up. Another important
limitation is the high drop-out rate (27.3%) observed at follow-up
in the D-XT group. The risk of losing patients at follow-up in RTSA
clinical studies is mainly related to the age: death or deteriora-
tion of general condition are common reasons of drop-out
among elderly patients. However, the clinical experience of a
single surgeon with two different implants provides some food for
reflection on recent history of RTSA.

Grammont’s intuitions revolutionized the world of shoul-
der arthroplasty: despite the initial skepticism, his Delta
prosthesis conquered the market thanks to the outstanding
effectiveness in treating cuff-deficient shoulders. The early
clinical experience predictably highlighted the biomechani-
cal limits of the reverse configuration and their potential
consequences. Moreover, the incidence of major complica-
tions, such as infection, instability, or implant failure, was
generally high, even if appreciably influenced by preopera-
tive diagnosis.

For two decades, much research has been devoted to
develop new design solutions and refine implantation tech-
niques, to overcome drawbacks of the first generation pro-
thesis and improve clinical outcomes, particularly in the
medium and long term. In our experience, the short-term
results achieved with two different generations of Delta
prosthesis exhibited subtle clinical differences in terms of
shoulder functional recovery. Conversely, radiographic find-
ings of the second generation implant showed a clear de-
crease in scapular notching, which might be important in the
perspective of improving long-term results and survival rates.

RTSA is still an evolving field of study. Alternative solu-
tions to the original biomechanical principles of Grammont
have been adopted in some reverse prosthesis. Hopefully,
ongoing research and long-term clinical experiences will
show us which is the best way to go for further improving
outcomes and reliability of RTSA.

Conflict of Interest
F.A.G. reports personal fees from null, outside the submitted
work.

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