Background: The primary aim of this randomized, controlled, masked clinical trial was to compare the percentage of root coverage obtained with a coronally positioned flap plus acellular dermal matrix (ADM) allograft to that of a tunnel technique plus ADM 4 months post-surgically.

Methods: Twenty-four subjects with one site with ≥3 mm Miller Class I or II recession were treated and followed for 4 months. Twelve patients received a coronally positioned flap plus ADM and were considered the positive control group (CPF). The test group consisted of 12 subjects treated with a coronally positioned tunnel technique plus ADM (TUN). Subjects were randomly selected by a coin toss to receive the test or control treatment.

Results: The mean facial recession defect at the initial examination for the TUN group was 3.1 ± 0.3 mm; this was reduced to 0.7 ± 0.9 mm at the 4-month examination for a gain of 2.4 ± 1.0 mm or 78% defect coverage (P < 0.05). The mean facial recession defect at the initial examination for the CPF group was 3.4 ± 0.8 mm; it was reduced to 0.2 ± 0.3 mm at the 4-month examination for a gain of 3.2 ± 0.9 mm or 95% defect coverage (P < 0.05). There was no statistically significant difference between groups (P > 0.05).

Conclusions: The coronally positioned flap plus ADM produced a defect coverage of 95%, whereas the tunnel technique plus ADM produced only 78% coverage. This difference was considered clinically significant but was not statistically significant. J Periodontol 2008;79:1022-1030.

KEY WORDS
Esthetic surgery; extracellular matrix; gingival recession; surgical flap.

The tunnel procedure for root coverage was introduced in 1994 and was termed the supraperiosteal envelope.1,2 The unique characteristic of this procedure was that the interdental papillae were left intact. A connective tissue graft was placed in the tunnel, but it did not need to be completely covered as long as the graft dimension was sufficient to ensure graft survival. An advantage of not covering the graft completely was that additional keratinized tissue was gained, whereas a disadvantage was that the exposed tissue might not be an exact color match. Conversely, the absence of vertical incisions had a tendency to produce better esthetics. Probably the main advantage of the technique was the minimally invasive nature of the surgery, which resulted in negligible postoperative discomfort at the recipient site.

Recently, the tunnel technique was modified to include coronal positioning of the marginal tissue, which allowed complete coverage of the graft (E.P. Allen, Center for Advanced Dental Education, Dallas, Texas; course manual). This was accomplished by dissecting more deeply to free up the facial tissue and by lifting the papillae off the interproximal septum from the facial and lingual aspects. These two features allowed greater coronal mobilization of the tissue margin. Successful execution of the
technique requires almost a microsurgical approach using smaller, specially designed instruments, small sutures, and a unique suturing technique. An advantage of the coronally positioned tissue margin was that the choice of graft material could now include acellular dermal matrix (ADM), which works best when completely covered. This technique allows a minimally invasive surgical procedure with no need to harvest palatal tissue. Thus, only a single surgical site is involved, and there are minimal complications or postoperative discomfort.

ADM placed under a coronally positioned flap was repeatedly shown to work as well as a connective tissue graft procedure in terms of mean percentage defect coverage and the predictability of gaining 100% coverage. It also increases tissue thickness and, from a histologic standpoint, attaches to the tooth in a similar fashion to connective tissue. i.e., the amount of long junctional epithelial attachment and connective tissue attachment is similar between the two procedures.

ADM is an allograft of human dermis. All cells have been removed, thus eliminating the possibility of graft rejection. The remaining extracellular matrix is left structurally intact, including vascular channels, as the result of a freeze-drying process that does not cause ice crystal formation. Production of ice crystals damages the structural integrity of the tissue matrix needed to encourage revascularization and cell repopulation. Thus, the healing process with ADM resembles tissue regeneration that is due to graft incorporation and replacement rather than the scar tissue formation that occurs when the extracellular matrix is structurally damaged.

The primary aim of this randomized, controlled, masked clinical trial was to determine whether the coronally positioned tunnel procedure results in predictable recession defect coverage compared to a coronally positioned flap, using an ADM graft with both procedures. A second aim was to compare the soft tissue thickness obtained with both procedures. The third and final aim was to determine whether creeping attachment occurred in either treatment groups.

**Study Design**
Twenty-four subjects who had at least one site with a Miller Class I or II recession defect ≥3 mm received root coverage surgery and were followed for 4 months. Twelve subjects in the positive control group were treated with a coronally positioned flap plus an ADM allograft (CPF). The test group consisted of 12 subjects who were treated with a coronally positioned tunnel technique plus an ADM allograft (TUN). The surgical technique for the test site was a modification of the tunnel procedure described by Allen, whereas the CPF technique was described by Dodge et al. Subjects were randomly selected to receive the test or control treatment using a coin toss. One operator (GP) performed all surgical procedures under the direction of a mentor (HG). The surgeon was trained in the procedures until considered proficient. This proficiency was evidenced by his result with the CPF, which was consistent with all previous studies at this institution, where ≥95% root coverage was obtained. No previous data on the coronally positioned tunnel were available for comparison. All subjects signed an informed consent approved by the University of Louisville Institutional Review Board in July 2006.

**Subject Selection**
Twenty-four subjects who met the following inclusion criteria participated in this study: at least one Miller Class I or II recession defect ≥3 mm on a canine, premolar, or incisor and age between 18 and 90 years. Subjects were excluded if any of the following criteria were present: debilitating systemic or infectious diseases (human immunodeficiency virus or hepatitis) or any disease that affects the periodontium; a known allergy to any of the materials used in the study; requirement for antibiotic prophylaxis; cemento-enamel junction (CEJ) not identifiable; a root surface restoration at the recession site; failure to maintain an oral hygiene level ≥80% plaque-free surfaces; pregnancy or lactation; use of tobacco products through smoking or a smokeless tobacco habit; alcohol abuse problems; long-term steroid therapy; history of a root coverage procedure, graft, or guided tissue regeneration involving the recession site; and failure to complete the informed consent. Subjects were given oral hygiene instructions and an adult prophylaxis prior to inclusion in the study.

**Baseline Data**
Baseline data included the following: Miller classification of the recession defect; plaque index; gingival index, bleeding on probing using dichotomous scoring; recession; keratinized tissue; probing depth; clinical attachment level; tooth mobility; creeping attachment measured from 8 weeks post-surgery until the final examination; tooth vitality tested using an electric pulp tester and a cold test; radiographs using a paralleling technique to take a preoperative periapical and bitewing radiograph; and gingival thickness at recession sites measured using an ultrasound meter.

**Surgical Treatment**
The surgical procedure for the control sites (Fig. 1) consisted of a coronally positioned flap. The ADM allograft was positioned at the CEJ and extended ~3 mm apically beyond the osseous defect margins. A bioabsorbable monofilament polyglyconate 5-0 sling suture was used to secure the graft and the flap.
The flap margin was positioned slightly coronal to the CEJ to completely cover the defect and ADM. The flap was sutured with a single tooth line angle sling suture. The releasing incisions were closed with interrupted sutures.

The test sites (Fig. 2) were treated with a tunnel preparation without any vertical releasing incisions. This tunnel was modified to include coronal positioning (E.P. Allen, Center for Advanced Dental Education, Dallas, Texas; course manual). The tissue was elevated using a split-thickness incision beyond the mucogingival junction and extended apically until adequate release was obtained to permit adequate coronal positioning. The tunnel was dissected using a specialized microsurgical kit without the use of a microscope or loupe. The tunnel and the ADM were extended at least one tooth mesial and distal to the recession site. Interproximal papillae were elevated off the interproximal septum on the facial and lingual aspects to facilitate coronal positioning. In cases where access was difficult, an incision was made to release the papilla to prevent tearing the tissue as the tunnel was dissected. The ADM was sutured in an identical manner as the coronally positioned flap sites using a polyglyconate suture that maintained tensile strength for at least 6 weeks. As a modification of the suturing technique, a 5-0 polyglyconate suture material was used for the soft tissue, whereas the course manual specified a 7-0 polypropylene suture.

Postoperative instructions were given along with the following prescriptions: systemic doxycycline hyclate, 50 mg, once a day for 14 days; naproxen, 375 mg, every 12 hours for 7 days; hydrocodone bitartrate, 7.5 mg, with acetaminophen, 750 mg, every 6 to 8 hours as needed for pain; and a dose pack of 21 tablets of methylprednisolone, 4 mg, six tablets on day 1, five tablets on day 2, and decrease by one tablet per day until the last one-tablet dosage on day 6. An alternative steroid regimen was used if the surgery included at least three teeth: dexamethasone, 1 mg, three tablets per day for the first 3 days, then two tablets per day for the next 3 days, and then one tablet per day for the last 3 days always taken in the morning and chlorhexidine digluconate 0.12% applied twice daily locally to the surgical site until the end of the study period.

Postoperative Management
All subjects were seen weekly for 2 weeks, then every 2 weeks until 8 weeks postoperatively, and then monthly until the end of the study period. Suture removal took place after 3 to 4 weeks of healing. Postoperative visits consisted of supragingival plaque removal and oral hygiene reinforcement. Any subject who developed an adverse reaction to the materials used or showed attachment loss ≥2.0 mm was exited from the study to receive the appropriate treatment. Eight weeks postoperatively was considered the baseline for the measurement of creeping attachment. Creeping attachment was measured at 2 months and at the 4-month final examination. All baseline clinical measurements were repeated at the end of the 4-month evaluation period.

Calibration
All measurements were made by a masked examiner using a 15-mm University of North Carolina probe. The ultrasonic meter§ was used to measure gingival thickness. Intraexaminer reliability was established by at least two examinations on three subjects to achieve 70% exact measurements and 90% of measurements within 1.0 mm.

Statistical Analysis
Means ± SD were calculated for all parameters. The statistical significance of the data was analyzed using a two-way analysis of variance. The sample size of 12 gave 80% statistical power to detect a difference of 1 mm root coverage between groups.

RESULTS
Sixteen females and eight males with a mean age of 41 ± 13 years (range: 20 to 73 years) were included in the study. The CPF group consisted of six maxillary and six mandibular teeth: five maxillary canines, one maxillary premolar, one mandibular canine, and five mandibular premolars. The TUN group consisted of six maxillary and six mandibular teeth: one maxillary canine, five maxillary premolars, two mandibular premolars, and one mandibular premolar.

§ SDM, Austenal Dentaltechnische Produkte, Cologne, Germany.
canines, two mandibular premolars, and two mandibular incisors. Two subjects did not comply with postoperative instructions and were exited at the first postoperative visit. One maxillary tunnel case had a slight tear of the marginal tissue. This complication was considered a risk of the procedure; therefore, the subject was not excluded.

Clinical Indices
The mean plaque index was initially low (<1.0) and decreased slightly by 4 months for both groups. There were statistically significant differences between the initial and 4-month values but not between the groups (P<0.05). The mean gingival index was ~1.0 initially and remained at about the same level at 4 months for the CPF and TUN groups. There were no statistically significant differences between the initial and 4-month values or between the groups (P>0.05). There was no bleeding on probing at the initial or 4-month examination. Mobility was low initially (<0.5) and decreased slightly at 4 months for both groups (P<0.05). There were no statistically significant differences between the groups (P>0.05). There were no other postoperative complications. The surgical procedures were tolerated well by the subjects; however, the TUN group seemed to have less postoperative discomfort.

Probing Measurements
Mean probing depth was ~1 mm initially and remained low and essentially unchanged at 4 months for both groups. There were no statistically significant differences between the initial and 4-month values or between the groups (P>0.05). The mean clinical attachment level was located more apically initially, to a slightly greater degree than recession depths, but improved significantly by 4 months, similar to the amount of recession defect coverage for both groups (P<0.05). There were no statistically significant differences between the groups. Mean keratinized tissue was initially ~1 mm and increased by 0.6 to 0.8 mm for both groups (P<0.05; Table 1). The difference between the groups was not statistically significant (P>0.05).

Gingival Thickness
At the initial examination, the mean gingival thickness at the sulcus base for the TUN group was 0.7 ± 0.2 mm, which increased to 0.8 ± 0.3 mm at the 4-month examination (P<0.05; Table 1). For the CPF group, the mean gingival thickness at the sulcus base was 0.6 ± 0.1 mm at the initial examination, which increased to 1.1 ± 0.2 mm at the 4-month examination (P<0.05). There were no statistically significant differences between the groups (P>0.05). At the initial examination, the mean gingival thickness at the muco-gingival junction for the TUN group was 0.8 ± 0.2 mm, which increased to 1.0 ± 0.4 mm at the 4-month examination (P<0.05). For the CPF group, the mean gingival thickness was 0.7 ± 0.2 mm and
Tunnel Versus Coronally Positioned Flap

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1.3 ± 0.3 mm, respectively \((P < 0.05)\). There were no statistically significant differences between the groups \((P > 0.05; \text{Table 1})\).

**Creeping Attachment**

Creeping attachment, or the mean recession change from 2 to 4 months, increased from 0.5 ± 0.6 mm to 0.7 ± 0.9 mm for a mean increase in recession of 0.2 ± 0.4 mm for the TUN group \((P > 0.05)\). There was no change for the CPF group, which remained at 0.2 ± 0.4 mm \((P > 0.05)\). There were no statistically significant differences between the groups \((P > 0.05)\).

**Osseous Dehiscence**

The mean facial dehiscence defect depth at the initial examination was ∼2.75 mm greater than the mean recession defect depth for both groups.

**Gingival Recession**

The mean facial recession defect at the initial examination for the TUN group was 3.1 ± 0.3 mm, which was reduced to 0.7 ± 0.9 mm at 4 months for a defect coverage of 2.4 ± 1.0 mm or 78% \((P < 0.05; \text{Table 2})\). For the CPF group, the mean initial recession was 3.4 ± 0.75 mm, which was reduced to 0.2 ± 0.3 mm at 4 months for a defect coverage of 3.2 ± 0.9 mm or 95% \((P < 0.05; \text{Table 3})\). Mean root coverage, or the percentage of the root that was covered, rather than the recession defect, was 95% for the TUN group and 99% for the CPF group. Frequency data indicated that the predictability of obtaining ≥90% defect coverage was 50% (six of 12 sites) for the TUN group, whereas it was 83% (10 of 12 sites) for the CPF group (Tables 2 and 3).

**DISCUSSION**

The primary aim of this randomized, controlled, masked clinical trial was to compare a coronally positioned tunnel procedure in the test group (TUN) to a coronally positioned flap in the positive control group (CPF), using an ADM allograft with both techniques. The TUN and CPF groups had a significant mean gain in recession defect coverage, 78% and 95%, respectively \((P < 0.05)\), whereas there were no statistically significant differences between the groups \((P > 0.05)\).

From a clinical standpoint, there was a clear difference between the two procedures. The CPF group had only 0.2 mm of mean residual recession at 4 months, whereas the TUN group had 0.7 mm. Also, a mean defect coverage of 78% for Miller Class I and II defects in the TUN group is a borderline unacceptable result, whereas the mean 95% coverage for the CPF group is within an acceptable range. Further, ≥90% defect coverage was achieved 10 of 12 times (83%) for the CPF group, whereas it occurred only six of 12 times (50%) for the TUN group. The 50% seen for the tunnel group is not an acceptable level of predictability.

Previous studies \(^3,5,8,10\) at the University of Louisville achieved ≥90% mean recession defect coverage using CPF plus ADM, and this study confirms that this is a reproducible result. The failure of the TUN procedure to achieve that same level of success may indicate that this is a more technique-sensitive procedure than the CPF. The recommended technique requires specially designed microsurgical instruments, small sutures designed for microsurgery, and a unique suturing technique for root coverage procedures. Thin marginal tissue is easily torn during the dissection if the operator is not extremely careful. Modifications to the technique may be needed to increase its level of predictability.

Another possible explanation for the difference in the results is that the use of vertical releasing incisions increases the predictability of achieving adequate coronal positioning and complete defect coverage. Felipe et al. \(^17\) compared a coronally positioned flap with releasing incisions to an envelope flap without releasing incisions when using ADM as a graft material for both procedures. \(^18,19\) The procedure with releasing incisions achieved ∼85% defect coverage, whereas the procedure without releasing incisions resulted in only 69% defect coverage. Thus, the CPF with releasing incisions achieved ∼16% more recession defect coverage than did the TUN procedure without releasing incisions. In this study, the CPF achieved 95% defect coverage, whereas the tunnel procedure resulted in only 78% coverage. This is 17% greater defect coverage for the procedure with releasing incisions, which is similar to the 16% greater defect coverage reported by Felipe et al. \(^17\) This similarity in the results could indicate that releasing incisions are an advantage when coronal positioning is needed. Another explanation is that procedures without releasing incisions are more technique sensitive when using ADM as a graft material. A third possibility is that procedures without releasing incisions are more prone to marginal

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**Table 1.**

**Thickness and Keratinized Tissue Measurements (mm; mean ± SD) for Test and Control Sites**

<table>
<thead>
<tr>
<th></th>
<th>TUN</th>
<th>Initial</th>
<th>4 Months</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness at sulcus base</td>
<td>TUN</td>
<td>0.7 ± 0.2</td>
<td>0.8 ± 0.3</td>
<td>0.1 ± 0.2*</td>
</tr>
<tr>
<td></td>
<td>CPF</td>
<td>0.6 ± 0.1</td>
<td>1.1 ± 0.2</td>
<td>0.5 ± 0.2*</td>
</tr>
<tr>
<td>Thickness at MGJ</td>
<td>TUN</td>
<td>0.8 ± 0.2</td>
<td>1.0 ± 0.4</td>
<td>0.2 ± 0.3*</td>
</tr>
<tr>
<td></td>
<td>CPF</td>
<td>0.7 ± 0.2</td>
<td>1.3 ± 0.3</td>
<td>0.6 ± 0.4*</td>
</tr>
<tr>
<td>Keratinized tissue</td>
<td>TUN</td>
<td>1.2 ± 0.8</td>
<td>1.8 ± 0.9</td>
<td>0.6 ± 0.5*</td>
</tr>
<tr>
<td></td>
<td>CPF</td>
<td>1.0 ± 0.5</td>
<td>1.8 ± 0.9</td>
<td>0.8 ± 0.7*</td>
</tr>
</tbody>
</table>

MGJ = mucogingival junction.

* \(P < 0.05\) comparing initial to 4-month values.
retraction over time when ADM is used as a graft material. A fourth explanation is that the TUN procedure did not allow enough coronal positioning to achieve predictable, complete root coverage. Pini Prato et al. showed that following a CPF, the more coronal the final gingival margin position, the greater the likelihood of complete root coverage. Thus, the limitation of coronally positioning the gingival margin following a tunnel procedure may affect its predictability when ADM is used as a graft.

There was a strong clinical impression among the authors that the coronally positioned tunnel procedure resulted in much less postoperative discomfort than the CPF technique. This impression was not systematically documented because this was not a paired defect study. However, the impression was so compelling that TUN is considered the technique of choice when it is indicated. Modifications of the technique need to be studied in an attempt to improve its predictability.

A surprising result was that the TUN group had only a minimal increase in soft tissue thickness; 0.1 mm, whereas the CPF group increased by ~0.5 mm. Previous studies consistently showed that ADM increased tissue thickness by 0.4 to 0.5 mm. The lack of increase in the TUN group indicates that the surgical technique did not ensure that the ADM became incorporated into the overlying soft tissue. This resulted in a borderline inadequate mean final marginal tissue thickness of 0.8 mm for the TUN group, whereas it was 1.1 mm in the CPF group. Baldi et al. indicated that marginal tissue thickness ≥0.8 mm can be coronally positioned predictably for complete root coverage, whereas tissue with less thickness will require a graft. Allen and Miller also indicated that thick marginal tissue (~1 mm) was needed for successful root coverage with a coronally positioned flap alone. Also, thin marginal tissue is generally considered more prone to additional recession than thick tissue.

Keratinized tissue increased by 0.8 mm for the CPF group in this study, which is identical to two previous studies. Mehlbauer and Greenwell found an increase of 2.0 mm, whereas other

### Table 2.
Recession, Defect Coverage, and Root Coverage for Test Teeth Treated With the Tunnel Procedure

<table>
<thead>
<tr>
<th>Subject</th>
<th>Recession Class</th>
<th>Tooth #</th>
<th>Defect Coverage</th>
<th>Defect Elimination</th>
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</thead>
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<td>Initial Recession</td>
<td>4-Month Recession</td>
<td>Recession Defect</td>
<td>Recession Defect Coverage</td>
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<table>
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<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>Frequency</th>
<th>Mean (SD)</th>
<th>Frequency</th>
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<td>3.1 (0.3)</td>
<td>0.7 (0.9)</td>
<td>2.4* (1.0)</td>
<td>78 (29)</td>
<td>6 of 12 (50%)</td>
</tr>
</tbody>
</table>

* P<0.05 comparing initial to 4-month values.

— Papageorgakopoulos, Greenwell, Hill, Vidal, Scheetz

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studies\textsuperscript{4,6,7,9,17,18,28-35} showed increases ranging from 0.4 to 2.2 mm. The TUN group showed a 0.6-mm increase, which is within the expected range.

There was no creeping attachment for the CPF group. This is consistent with previous results when ADM was used as a graft material.\textsuperscript{5,8,10} However, the TUN group showed an increase in recession from 2 to 4 months. This indicates a tendency for marginal tissue retraction after 2 months of healing. In general, the result is considered stable after the 2-month time point: there is a gain in creeping attachment or no change. The slight loss that occurred in the TUN group was unexpected and may have been related to the lack of increase in tissue thickness. A longer-term study may be indicated to evaluate the marginal tissue stability for the coronally positioned tunnel using ADM.

**CONCLUSIONS**

The coronally positioned tunnel technique did not compare well with the CPF procedure and achieved only 78% defect coverage, whereas there was 95% coverage for the CPF group. Also, the predictability of achieving ≥90% defect coverage was 50% for the TUN group versus 83% for the CPF group. However, subjects in the TUN group almost uniformly reported negligible postoperative discomfort. The tunnel approach is a valuable treatment option because of its minimally invasive nature and its lack of postoperative complications and discomfort. Modifications to the surgical procedure are needed to increase its predictability, and an investigation is underway to test a revised technique.

**ACKNOWLEDGMENTS**

This study was partially supported by a grant from BioHorizons, Birmingham, Alabama. Drs. Papageorgakopoulos, Hill, Vidal, and Scheetz report no financial relationship to any product involved in this study. Dr. Greenwell gives lectures sponsored by BioHorizons.

**Table 3.**

Recession, Defect Coverage, and Root Coverage for Control Teeth Treated With a Coronally Positioned Flap

<table>
<thead>
<tr>
<th>Subject</th>
<th>Recession Class</th>
<th>Tooth #</th>
<th>Initial Recession Defect</th>
<th>4-Month Recession Defect</th>
<th>Recession Defect Coverage</th>
<th>Mean Defect Coverage (%)</th>
<th>Frequency ≥90% Defect Coverage</th>
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<td>2.5</td>
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<td>0.0</td>
<td>93</td>
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<table>
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<th>Frequency</th>
<th>Mean (SD)</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>3.4 (0.8)</td>
<td>0.2 (0.3)</td>
<td>3.2* (0.9)</td>
<td>95 (10)</td>
<td>10 of 12 (83%)</td>
</tr>
<tr>
<td>99 (3)</td>
<td>12 of 12 (100%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P <0.05 comparing initial and 4-month values.
REFERENCES


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