RHYTIDES, LAXITY AND PHOTOAGING TREATED WITH A COMBINATION OF RADIOFREQUENCY, DIODE LASER, AND PULSED LIGHT AND ASSESSED WITH A COMPREHENSIVE GRADING SCALE

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Abstract
Several classes of nonablative laser and light technologies have been developed to target laxity, rhytides, and the various aspects of photoaging. The combination of the 3 main classes of nonablative rejuvenation, infrared laser, intense pulsed light, and radiofrequency energy are assessed in the current study. Using a comprehensive grading scale developed to evaluate the multiple categories of the aging skin, quantitative analysis of changes in each category as well as overall improvement and patient satisfaction were calculated. The combination technology resulted in a patient mean (95% CI) % improvement per category of 10.9% (8.1-13.7) per treatment and 26.0 (16.5-35.5) % overall following a mean (±SD) of 2.4 (±1.2) treatments. In addition, the patient satisfaction was 71.4 %, suggesting that combining nonablative technologies may maximize clinical results and patient detection of improvement.

Introduction
Nonablative laser and light technologies are in high demand as patients are willing to trade the greater cosmetic improvement obtained from ablative or surgical interventions, in exchange for the minimal risk, rapid recovery, and acceptable improvement associated with the nonablative approach. A variety of nonablative technologies have emerged, designed to improve specific aspects of skin aging. Aging of the skin can be divided into 2 main categories: 1) intrinsic aging, due to genetic factors such as telomere shortening and characterized by laxity and deep rhytides and 2) aging due to ultraviolet (UV) damage, termed photoaging or photodamage, and characterized by dyschromia, elastosis, fine rhytides, erythema, telangiectasia, textural changes, and keratoses.1 Nonablative systems may be classified into 3 main groups based on their targets: 1) infrared (IR) lasers, which target the dermis and induce neocollagenesis, minimizing rhytides;2-4 2) intense pulsed light (IPL) sources, which primarily target pigment and blood vessels, improving dyschromia and erythema-telangiectasia,1 and 3) radiofrequency (RF) devices, which induce collagen contracture, primarily targeting laxity.5-7 Thus, different classes of nonablative technologies have emerged treating specific aspects of aging of the skin, yet a comprehensive treatment modality globally improving all categories of skin aging would be highly desirable.

A combined technology incorporating the 3 classes of nonablative technologies and targeting the 3 main aspects of skin aging—rhytides, laxity, and photoaging—in one treatment session would serve theoretically optimize clinical outcome. The combination of bipolar RF and 900-nm diode laser was evaluated previously in a blinded assessment of 49 patients, demonstrating improvement in rhytides and laxity.8 More recently, a device bipolar RF both with diode laser and with IPL has been developed, which combines the 3 main classes of nonablative technologies and their targets in one unit. In the current study, this combination technology is assessed for the treatment of skin aging by individual category and overall, and for patient satisfaction.

In order to assess the individual categories of skin aging, a grading scale was required that permits the independent grading of each category of skin aging and each aspect of photoaging. It has been noted that the well-accepted grading systems, such as the Glogau and Fitzpatrick scales, are primarily designed and used for evaluating ablative technologies, such as chemical peeling or carbon dioxide laser resurfacing, which result in global improvement in all aspects of skin aging, but do not individually assess each of the diverse aspects of the aging skin.8-10 Patients seeking nonablative treatments often do not fall nearly into any one global category and nonablative technologies target certain aspects of skin aging, but not all.

A comprehensive grading scale encompassing and individually assessing gradations of severity for the various aspects of skin aging, including rhytides, laxity, and the multiple components of photoaging has been designed (see Focus Column, this issue). This scale may used to assess the efficacy of nonablative or other laser resurfacing technologies and cosmetic treatment modalities for their clinical impact on each individual aspect of the aging skin, providing a more quantitative analysis of each category as well as overall improvement.

In the current study, a device combining RF, IR laser, and IPL is evaluated in 28 patients for the treatment of rhytides, laxity, and photodamage using the comprehensive grading scale. The quantitative effects of the combination system on each individual aspect of aging of the skin, overall improvement, and patient satisfaction are demonstrated.

Patients and Methods
Twenty-eight patients aged 45 to 75 of skin phototypes I to III were enrolled in the study. The inclusion and exclusion...
criteria for the study are listed below. Baseline photographs and grading evaluations were performed.

**Inclusion Criteria:**
1. Skin Type I to IV (Fitzpatrick).
2. Age: males and females older than 21 years of age.
3. Females must be either postmenopausal, surgically sterilized, or using a medically acceptable form of birth control, including oral contraceptives, IUD, contraceptive implant, barrier methods with spermicide, or abstinence.
4. Informed consent agreement by the subject.
5. Agreement by patient to follow the treatment schedule and post treatment care.

**Exclusion Criteria:**
1. Malignant or premalignant pigmented lesions.
2. Scarring or infection of the area to be treated.
3. Known photosensitivity.
5. Subjects with diabetes (Type I or II).
6. Presence of a suntan in the area to be treated.
7. Use of medication known to induce photosensitivity.
8. Known anticoagulative or thromboembolic condition.
9. Use of anticoagulation medication.
10. Use of isotretinoin within past 12 months.
11. Subjects with a pacemaker or internal defibrillator.
12. Use of NSAIDS 2 weeks before or after the treatment.
13. Prior treatment of the area with another laser or light device within 1 year of baseline visit.

A topical anesthetic agent of lidocaine and prilocaine cream (EMLA) was applied in a 1-to 2-mm layer to the facial and neck skin without occlusion for 1 hour prior to the procedure. The anesthetic cream was removed and room temperature aqueous gel was applied in a thin layer to the facial and neck skin.

Step 1: RF with 900-nm diode (Polaris, Galaxy, Syneron, Yokneam, Israel) was applied first. Initial treatments were started with the diode at a fluence of 20 J/cm² and RF of 50 J/cm² to the forehead and 80 J/cm² to the face and neck. Six to 10 passes were performed, until the clinical endpoint of erythema was achieved. Each pass was performed at right angles to the previous pass. At each subsequent treatment session, the diode fluence was increased by 2 to 4 J/cm² depending upon skin type to a maximum of 36 J/cm² in type I skin patients. RF was maintained at 50 J/cm² to the forehead, and increased by 10 J/cm² per treatment session to a maximum of 100 J/cm² to the face and neck.

Step 2: RF with IPL (500 to 1200 nm) (Aurora, Galaxy, Syneron, Yokneam, Israel) was applied second. A starting fluence of 20 J/cm² for the IPL and of 18 J/cm² for RF was applied in short-pulse mode and 2 successive passes. The IPL fluence was increased by 2 to 4 J/cm² per treatment to a maximum of 30 J/cm² in type I skin patients. The RF energy was increased by 2 J/cm² per treatment until reaching a maximum of 22 J/cm².

Cold packs were applied immediately after laser treatment to alleviate erythema. Each patient received 1 to 5 treatments at monthly intervals.

**Patient Assessments**
Investigator and photographic assessments were performed prior to each treatment and during the follow-up intervals. Following the final treatment, follow-up was performed at 1, 3, 6, and 12 months.

**Novel Grading Scale**
The grading scale is shown herein in Table 1 (see also Focus-On column, this issue).

**Statistical Analysis**
For each category, the pretreatment and posttreatment scores for each category were recorded, as were treatment number and final date of follow-up. Pretreatment scores were recorded at baseline on the date of the first treatment. Posttreatment scores were recorded the date of final follow-up.

Patient mean percent improvements were calculated as follows. For each category of rhytides, laxity, elastosis, dyschromia, erythema-telangiectasia, keratoses, and texture, the score difference was calculated as the posttreatment score – pretreatment score. The **patient percent improvement** was calculated as the score difference/pretreatment score and the **patient percent improvement per treatment** was calculated as the percent improvement/treatment number. The **mean percent improvement per individual category** was calculated as the mean of the patient percent improvements for that category. The **patient mean percent improvement per individual category per treatment** was calculated as the mean of the patient percent improvements per treatment. The **patient mean percent improvement per category overall** was calculated as the mean of the patient mean percent improvements per individual category. The **patient mean percent improvement per category overall per treatment** was calculated as the mean of the patient mean percent improvement per category per treatment.

The overall percent improvements were also calculated as follows. For each patient, the mean was calculated for the patient percent improvement for each individual category to obtain the **mean percent improvement overall**. The mean was also calculated for each patient percent improvement per treatment to obtain the **mean percent improvement overall per treatment**. The **overall mean percent improvement** was then calculated as the mean of means percent improvement overall. The **overall mean percent improvement per treatment** was calculated as the mean of means percent improvement overall per treatment.
Table 1. Comprehensive Grading Scale for Assessment of Rhytides, Laxity and Photodamage.

<table>
<thead>
<tr>
<th>Grading Scale</th>
<th>Descriptive Parameter</th>
<th>Categories of Skin Aging and Photodamage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rhytides</td>
</tr>
<tr>
<td>0</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>1</td>
<td>mild</td>
<td>wrinkles in motion, few, superficial</td>
</tr>
<tr>
<td>1.5</td>
<td>mild</td>
<td>wrinkles in motion, multiple, superficial</td>
</tr>
<tr>
<td>2</td>
<td>moderate</td>
<td>wrinkles at rest, few, localized, superficial</td>
</tr>
<tr>
<td>2.5</td>
<td>moderate</td>
<td>wrinkles at rest, multiple, localized, superficial</td>
</tr>
<tr>
<td>3</td>
<td>advanced</td>
<td>wrinkles at rest, multiple, forehead, periorbital and perioral sites, superficial</td>
</tr>
<tr>
<td>3.5</td>
<td>advanced</td>
<td>wrinkles at rest, multiple, generalized, superficial; few, deep</td>
</tr>
<tr>
<td>4</td>
<td>severe</td>
<td>wrinkles throughout, numerous, extensively distributed, deep</td>
</tr>
</tbody>
</table>
For each percentage above, the 95% confidence intervals (CI), variance, standard of deviation (SD), and standard of error of the mean (SEM) were calculated.

**Results**

**Adverse Events**

Among the 28 patients treated, adverse effects occurred in 3 patients. One female patient developed a single crust on the labella, which healed without scarring within 5 days. A male patient developed transient hair loss to the beard area, which regrew within 1 month. Another male patient developed a postoperative acne flare, consisting of 3 erythematous acneiform papules. No blistering or dyspigmentation was observed.

**Pain**

Pain was rated on a 0 to 3 scale (0 = none, 1 = mild, 2 = moderate, 3 = severe). The mean pain rating for step 1, the RF/diode laser step, was moderate at 2.1 +/- 0.8. For step 2, the RF/IPL procedure, the rating was markedly lower, 0.3 +/- 0.1, as the majority of patients sensed no discomfort. The discomfort was transient, occurring only during pulses, resolving completely immediately postprocedure.

**Erythema**

The degree of postoperative erythema was rated by the investigator immediately postprocedure using the same 0 to 3 scale used for pain. Mean erythema was 1.5 +/- 0.7. Erythema resolved promptly within 1 hour in the majority of patients. In 2 patients, erythema persisted for several hours, but resolved without sequelae.

**Comprehensive Grading Scale Assessments**

<table>
<thead>
<tr>
<th>Category</th>
<th>Rhytides</th>
<th>Laxity</th>
<th>Elastosis</th>
<th>Dyschromia</th>
<th>Erythema-Telangiectasia</th>
<th>Keratoses</th>
<th>Texture</th>
<th>Patient Mean per Category</th>
<th>Overall Mean per Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Rx</td>
<td>9.6</td>
<td>9.9</td>
<td>12.9</td>
<td>10.0</td>
<td>4.1</td>
<td>7.8</td>
<td>21.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>(6.7-12.6)</td>
<td>(6.6-13.2)</td>
<td>(6.7-19.0)</td>
<td>(4.6-15.4)</td>
<td>(0.9-7.3)</td>
<td>(2.8-12.8)</td>
<td>(13.5-30.3)</td>
<td>(8.1-13.7)</td>
<td>(5.8-16.0)</td>
</tr>
<tr>
<td>Overall</td>
<td>20.4</td>
<td>22.6</td>
<td>32.7</td>
<td>28.6</td>
<td>10.7</td>
<td>23.8</td>
<td>43.1</td>
<td>25.99</td>
<td>25.63</td>
</tr>
<tr>
<td></td>
<td>(14.2-26.5)</td>
<td>(15.9-29.3)</td>
<td>(19.0-46.5)</td>
<td>(13.8-43.3)</td>
<td>(3.0-18.4)</td>
<td>(9.8-37.8)</td>
<td>(32.0-54.3)</td>
<td>(16.52-35.45)</td>
<td>(18.34-32.93)</td>
</tr>
</tbody>
</table>

The mean percent improvement (95% CI) for each category of aging of the skin. As described in Patients and Methods, the patient mean % improvement per individual category was calculated as the mean of the patient % improvements for that category and listed in the row labeled “Overall”. The patient mean % improvement per individual category per treatment was calculated as the mean of the patient % improvements per treatment and listed in the row labeled “Per Rx”. The patient mean % improvement per category overall was calculated as the mean of the patient mean % improvements per individual category and listed in the column labeled “Patient Mean per Category” in the row labeled “Overall.” The patient mean % improvement per category overall per treatment was calculated as the mean of the patient mean % improvement per category per treatment and listed in the column labeled “Patient Mean per Category” in the row labeled “Per Rx”. For each patient, the mean was calculated for the patient % improvement for each individual category to obtain the mean % improvement overall. The mean was also calculated for each patient % improvement per treatment to obtain the mean % improvement overall per treatment. The overall mean % improvement was then calculated as the mean of means % improvement overall and listed in the final column, bottom row. The overall mean % improvement per treatment was calculated as the mean of means % improvement overall per treatment and listed in the final column, top row.

Among the 28 patients treated, the treatment number ranged from 1 to 5 with a mean of 2.4 +/- 1.2 treatments per patient. The patient mean percent improvements per treatment are presented in Table 2. These data are analyzed for each category and overall score per treatment. The results are subdivided according percent improvement for rhytides, laxity, and each category of photodamage. For the overall score, no weighting of categories was performed.

The patient mean percent improvement (95% CI) for each category of assessment per treatment was calculated as the mean of the patients’ percent improvement from pretreatment to posttreatment scores divided by the treatment number for each patient (see Patients and Methods). The patient mean percent improvement (95% CI) for each category of assessment per treatment was as follows: rhytides, 9.6% (6.7% to 12.6%); laxity, 9.9% (6.6% to 13.2%); elastosis, 12.9% (6.7% to 19.0%); dyschromia, 10.8% (4.6% to 15.4%); erythema-telangiectasia, 4.1% (0.9% to 7.3%); keratoses, 7.8% (2.8% to 12.8%); and texture, 21.9% (13.5% to 30.3%) (Table 2). The patient mean percent improvement per treatment across all categories was then calculated as the mean of means percent improvement for each patient. The patient mean percent improvement per treatment of all categories was 10.9% (8.1% to 13.7%). This value controlled for interpatient variability in responsiveness to the intervention. Analyzing the data by category and averaging the percent improvement among all patients per category, the overall mean percent improvement was calculated as the mean of means percent improvement per category. The overall mean percent improvement per treatment (95% CI) was 10.9% (5.8% to 16.0%) (Table 2).

The improvement among the patients without controlling for treatment number was also calculated. The patient mean...
percent improvement (95% CI) for each category of assessment was as follows: rhytides, 20.4% (14.2% to 26.5%); laxity, 22.6% (15.9% to 29.3%); elastosis, 32.7% (19.0% to 46.5%); dyschromia, 28.6% (13.8% to 43.3%); erythema-telangiectasia, 10.7% (3.0% to 18.4%); keratoses, 23.8% (9.8% to 37.8%); and texture, 43.1% (32.0% to 54.3%). The patient mean percent improvement per category overall, calculated as the mean of above means and controlling for interpatient variability, was 26.0% (16.5% to 35.5%). The overall patient mean percent improvement was similar at 25.6% (18.3% to 32.9%).

Photographic examples of patients prior to and following treatment are shown in Figures 1 to 5. Each figure demonstrates improvement in several aspects of rhytides, laxity, and photodamage, as shown.

**Patient Satisfaction**
Among the 28 patients, 20 (71.4%) were satisfied with the outcome as opposed to 8 (28.6%) who were unsatisfied. Patient satisfaction was rated on a binary yes/no scale.

**Follow-up**
Patients were followed up for a mean of 6 +/- 3.5 months (range 1 to 12 months).

**Discussion**
Nonablative technologies have been honed to target specific aspects of the aging skin. In the current study, a combination approach incorporating the 3 main categories of nonablative technologies has been shown to improve all aspects of skin aging as assessed with a comprehensive grading scale. A combination of RF with near-IR laser and IPL improved each category of skin aging including rhytides, laxity, and the various aspects of photodamage as assessed by a quantitative grading scale. The combination technology resulted in a patient mean (95% CI) percent improvement per category of 10.9% (8.1% to 13.7%) per treatment and 26.0% (16.5% to 35.5%) overall following a mean of 2.4 +/- 1.2 treatments. In addition, the patient satisfaction was 71.4%, an important criterion that needs to be assessed in order for a new technology to be successful long-term.

While the improvement per category per treatment of 10.9% is mild, the fact that all categories of rhytides, laxity, and photodamage demonstrated improvement from a nonablative treatment is significant. In the past, ablative and fractionally ablative laser resurfacing have yielded global improvements in all aspects of skin aging, whereas nonablative treatments were efficacious in specific subsets of categories, but not all. The use of IPL mainly impacts pigment and vascular abnormalities, while inducing minimal clinical improvement in rhytides. The IR lasers, including the Nd:YAG laser at 1320 nm with a pulse duration of 200 µsec, the diode laser at 1450 µm and the Erbium:glass laser at 1540 msec have resulted in mild-to-moderate improvement in rhytides and scars, with histologic evidence of neocollagenesis, but without significant clinical improvement to laxity or photodamage. The first RF energy source, the monopolar RF device, ThermaCool (Thermage), targeted skin laxity of the face and neck, with demonstrable results in a minority of patients, but without significantly impacting other aspects of photoaging. In contrast, the current study demonstrates that by combining the 3 main categories of nonablative technologies, consistent mild improvement in all categories of skin aging may be achieved.

The incorporation of IPL (500 to 1200 nm) into a combination nonablative approach targets both melanin and hemoglobin, resulting in improvement in dyspigmentation and vascularity, the 2 main aspects of photoaging. The term “photorejuvenation” was coined to describe the global improvement in multiple parameters of photodamage that is observed with the IPL. While IPL use has been reported to induce modest clinical improvement in rhytides, it causes dramatic changes in pigment and vascular abnormalities of photodamaged skin. These clinical changes have been...
Figure 3. Skin laxity improvement following a single treatment with combination RF, IR laser, and IPL. Prominent melolabial folds in patient #7 prior to (A) and following a single treatment (B). The patient's laxity score was rated at 3 prior to and 2 following treatment, yielding a patient percent improvement per treatment of 33.3% in laxity. This result was maintained to 9 months follow-up.

Figure 4. Severe rhytides, advanced skin laxity, and elastosis improved following a single treatment. This patient (#13) was rated prior to treatment (A) with severe rhytides (score = 4), advanced laxity (score = 3), and severe elastosis (score = 4). Following a single treatment (B), rhytides were rated at 3, laxity at 2.5, and elastosis at 2. The patient percent improvement per treatment was 25% for rhytides, 16.7% for laxity, and 50% for elastosis.

Figure 5. Advanced to severe rhytides, laxity, and photoaging treated by combination RF, IR laser, and IPL. This example illustrates a patient with advanced (score = 3 to 3.5) to severe (score = 4) pretreatment ratings in all categories prior to (A) and following (B) 3 treatments. Patient #17 demonstrated a mean percent improvement overall (see Patients and Methods) of 22.9% and per treatment of 7.6%.
correlated with histologic changes indicative of a dermal remodeling effect, such as an increase in extracellular matrix proteins and neocollagenesis. The patient perception of improvement may be largely attributed to the decreases in dyspigmentation and vascularity, which are more easily detectable than mild changes in rhytides. This study supports these findings, with patient mean (95% CI) percent improvement in dyschromia and erythema-telangiectasia, respectively, of 10.0% (4.6% to 15.4%) and 4.1% (0.9% to 7.3%) per treatment and of 28.6% (13.8% to 43.3%) and 10.7% (3.0% to 18.4%) overall (Table 2, Figure 2). In addition, patient satisfaction was high at 71.4%, which may be explained in part by the ease of detecting visual changes in pigment and vascularity.

The combination device also incorporates a near-IR laser, the first class of lasers to be definitively associated with nonablative rejuvenation and to mildly improve rhytides. In this study, mild improvement in rhytides was demonstrated with a patient mean (95% CI) percent improvement of 9.6% per treatment (6.7% to 12.6%) and 20.4% (14.2% to 26.5%) overall (Table 2, Figures 1, 2, 4, 5). These findings are consistent with prior studies employing this class of nonablative laser technology. The prototype of nonablative rejuvenation was the IR Nd:YAG laser at 1320 nm with a pulse duration of 200 µsec followed by the diode laser at 1450 µm and the erbium-glass laser at 1540 µsec. Mild but reproducible improvement in rhytides and scars and histologic evidence of neocollagenesis 6 months after treatment have been reported with these lasers. Two studies of the 1320 nm Nd:YAG laser demonstrated minimal to mild improvement in the majority and moderate improvement in the minority. Similar results were obtained using the 1450-nm diode, with mild improvement of periorbital and perioral rhytides. The 1540-nm erbium-doped phosphate glass laser yielded mild to moderate improvement in rhytides and histologic increases in dermal collagen months after treatment. Among 60 patients with periorbital and perioral rhytides treated with the 1540 nm Er:glass laser, a mean increase in dermal thickness of 17% and patient satisfaction of 62% were reported. The drawback of IR laser for nonablative skin rejuvenation has been that it induces only dermal changes and is of limited benefit for patients with photaging who have both epidermal and dermal changes. In the current combined technology approach, the IR laser component likely targets rhytides, as was demonstrated previously. When IR laser is applied concomitantly with RF and in succession with IPL, as in the current study, it provides the advantage of treating the other aspects of photodamage as well (Figure 5).

In an effort to increase penetration depth and achieve collagen shrinkage, RF wavelengths have been employed, and this third class of nonablative rejuvenation is incorporated in the system evaluated here. RF devices produce electrical energy that delivers a uniform volumetric heating effect into the deep dermis, generated by the tissue’s resistance to the current flow. The first energy source in this arena was a monopolar RF device (Thermacool) which demonstrated improvement in skin laxity on the face and neck. During its initial use, disadvantages of that system were inconsistent results with dramatic improvement in a minority of patients and minimal changes in the majority, with only one-third of patients reporting satisfaction with the outcome. Recent modifications to the procedure have improved consistency of results by increasing the tip size and performing multiple passes at lower energy settings. The combination of electrical and optical energy was subsequently introduced in order to augment the nonablative effects achieved either modality alone. The combination of a 900-nm IR laser and bipolar RF has been shown to mainly improve skin laxity, rhytides, elastosis, and dyschromia. In the current study, a technique of multiple (6 to 10) passes was performed using the RF at near-maximum or maximum (90 to 100 J/cm²) fluence, resulting in significant improvement following a single treatment (Figure 3). The patient mean % improvement in skin laxity was 9.9% (6.6% to 13.2%) per treatment and 22.6% (15.9% to 29.3%) overall, which may be attributable in large part to the RF component, though this was not directly tested independent of the other components in the system (Table 2).

Despite the current and prior studies demonstrating the effectiveness of the system described here, the comparison control of the IR laser or IPL without RF is lacking which would test the hypothesis regarding a synergistic effect of the RF on outcome. It is possible that the combination of electrical energy with the IR laser or the IPL augments the effects of either component alone, however this has not been directly assessed. In the current study, the goal was the multifaceted assessment of the combination treatment, rather than an evaluation of each of the three components independently of each other. The main disadvantage of the current study is the lack of these controls, thereby limiting the ability to directly attribute any of the results observed to a given component of the system. Any conclusions one may draw regarding which component yielded improvements in subsets of categories of skin aging are therefore speculative. Nevertheless, given the plethora of published data in the literature and aforementioned regarding the targets in the skin and the clinical outcomes obtained through the independent use of IPL, IR laser, or RF systems, the conclusions drawn here regarding the likely effects of each of these components to the system are plausible and logical.

References
6. Jacobson LG, Alexiades-Armenakas MR, Bernstein L, and


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