# Peri-Implant Marginal Bone Changes and Soft Tissue Conditions around Single Implants with Laser-Microgrooved Collar Placed in Regenerated Extraction Sockets and in Native Bone: 2-Year Results of RCT

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**Abstract**

The aim of present study was to compare peri-implant marginal bone changes and soft tissues conditions around single implants placed in alveolar sockets regenerated with porcine xenograft and collagen membrane or non-regenerated native bone.

Forty patients who required single tooth extraction and single implant placement in premolar/molar area, were enrolled in this study. Subjects were randomly assigned to the control group (S; extraction sockets spontaneously healed) or to the test group (R; extraction sockets grafted with porcine-derived bone and covered with collagen membrane). Six months after extractions, single tapered implants with laser-microgrooved collars were inserted. For each implant, radiographic MBL and clinical parameters were evaluated during 2 years of function.

At the 24-month follow-up, a survival rate of 100% was reported for all implants. For the S group, the mean marginal bone loss (MBL) was 0.118 ± 0.07 mm while for the R group the mean MBL was 0.131± 0.03 mm. No statistically significant differences were reported among groups (P >0.05). Between the two groups, no statistically significant differences were found also for plaque index, bleeding on probing, probing depth and gingival recession.

At the 24-month follow-up, results showed that implants with laser-microgrooved collar surface placed in regenerated extraction sockets and in native bone did not performed differently with respect to implant survival, MBL and peri-implant soft tissue parameters.

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## Introduction

In the last years, missing teeth are increasingly replaced by dental implants,[1] which are considered one of the best alternatives for the rehabilitation of the oral district.[2] Tooth loss due to caries or periodontal disease is very common in developing countries while it is decreasing in developed ones: however, dental implantology has become routinary and popular worldwide.[3]

In contemporary implant dentistry, the outcome of treatment should not be only evaluated in terms of implant survival, but also by the long-term aesthetic and functional success. This depends on implant ideal placement, that must be based on a restoration-oriented treatment plan, allowing the optimal support and stability of surrounding hard and soft tissues.[4] Moreover, since the contour of soft tissue depends on the underlying bone anatomy, the long-term aesthetic and functional outcome can also be infuenced by the amount of available bone in the implant site and its relation to soft tissues.[5]

After tooth extraction, the resorption and remodelling process of the alveolar walls is an inevitable phenomenon, which can negatively impact ideal implant placement.[6,7]

To counteract the post-extraction alveolar volume change, different ridge preservation techniques (RPT)s have been proposed.[8-14] Most of the techniques consist of filling the alveolar socket with different grafting materials with and without sealing the socket with absorbable or

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non-absorbable membranes. Grafting biomaterials have shown to provide better mechanical support during the healing and remodeling phase compared to spontaneous healing. Moreover, based on their osteogenic, osteoconductive, or osteoinductive properties, graft materials act as stimulants or scaffolds for bone growth.

Literature data indicated that, in partially edentulous patients, survival rate was similar between implants placed in sites previously treated with RPTs and in native bone.[15,16] However, few studies[17-19], reported comparative results regarding MBL and soft tissue parameters for implants placed in regenerated and non-regenerated extraction sockets. The aim of the present study was to evaluate whether or not implants placed in regenerated extraction sockets show the same success rates, and the same hard and soft tissue conditions as implants placed in native bone, after 2 years of function.

## Materials and methods

The present RCT included 40 patients who had received implants both in regenerated and non-regenerated extraction sockets of mandibular or maxillary premolar/molar areas. Public domain online software (Raosoft, http://www.raosoft.com/samplesize.html) was used to calculate the minimal number necessary for statistical evaluation. The study subjects (24 males and 16 females; age range 18 to 67 years: mean age 55.8 years) were treated from 2015 to 2018 by two clinicians (RG, LT) at the Department of Oral and Maxillofacial Sciences, University of Roma “La Sapienza”, Italy. The study was approved by the Research Ethics Committee of the La Sapienza University of Rome (#4597). Patients gave written consent, and the study was conducted according to the principles embodied in the Helsinki Declaration for biomedical research involving human subjects. Protocol registration at https://register.clinicaltrials.gov/NCT03686865.

Criteria for inclusion in the study were: age ≥ 18 years; good general health, no pregnancy, no uncontrolled metabolic disorders; presence of one hopeless tooth with a endodontic treatment failure, or root fracture, or endo-periodontal non-treatable lesion, absence at the intraoral periapical radiographies and CBCT examination of a severe wall defect (absence of vestibular or lingual socket wall, or > 50% missing vestibular/lingual socket wall), presence of adjacent teeth.

Criteria for exclusion were: history of systemic diseases that contraindicate oral surgery, long-term non-steroidal anti-inflammatory drug therapy, oral bisphosphonate therapy, pregnancy or lactation, unwillingness to return for the follow-up examinations, cigarette consumption > 10 per day. Using a computer-generated randomization list, patients were randomly assigned to the control group (S; extraction sockets spontaneously healed) or to the test group (R; extraction sockets grafted with porcine-derived bone and covered with collagen membrane).

In the R group, RPT involved grafting with a xenogenic bone substitute mineral (MinerOss XP®, BioHorizons, Birmingham, AL, USA) covered with a bio-resorbable collagen membrane (Mem-Lok Pliable®, BioHorizons, Birmingham, AL, USA). In the S group, no treatment was performed to the extraction sites.

Extractive surgical protocol: the surgical protocol used for first phase of the study was described in a previous publication.[20]

Implant placement protocol: After over 4 months of healing, the surgical reentry procedure was performed for implant placement. Before surgery, in each site, the KTT was measured after performing anesthesia, by means of n. 30 K-file inserted until touching the bone crest. The KTT was dichotomized into two groups (≤2 mm and >2 mm) in accordance with the results of an animal study performed by Berglundh et al.[21] Implants (Tapered Internal LaserLok®, BioHorizons, Birmingham, AL, USA) were placed, with the rough/microgrooved border flush with the bone crest, with the laser-microgrooved surface at the supra crestal level, and at a minimum distance of ≥1.5 mm from the adjacent natural teeth. Patients scheduled for surgery were prescribed systemic amoxicillin/clavulanic acid (Augmentin, Glaxo SmithKleine, Italy), 1 g, twice a day for 7 days, and a chlorhexidine digluconate solution 0.12% (Dentosan 0,12%, Johnson & Johnson, USA) (twice daily for 1 minute). After local anesthesia by infiltration using articaine/epinephrine, (Ecocain 20mg/ml, Molteni Dental, Italy,) surgical access was carried out with a full-thickness flap at the level of keratinized mucosa with a minimally extended release incision to expose the crest and the vestibular

limit of the bone. Utmost care was taken to preserve the periodontal integrity of adjacent teeth. Following implant placement, the flap was sutured without tension using 4.0 or 5.0 monofilament sutures which were left in place for 10 days. Patients were instructed to have a liquid or semiliquid diet for the first three days and gradually return to a normal diet. An analgesic (Ibuprofen®, 600 mg, Kern Pharma, Terrassa, Spain) was prescribed immediately after surgery and after 8 hours.

The second-stage surgery for placement of healing abutments was performed after 4 months in the mandible and 6 months in the maxilla. The implant supported prosthetic restorations were delivered in each implant site after 5 and 7 months in the mandible and maxilla respectively. All prosthetic restorations were screw-retained. In the S group, 12 implants were placed in the mandible (8 in premolar sites and 4 in molar sites), while 8 implants were placed in the maxilla (3 in premolar sites and 5 in molar sites). In the R group 11 implants were placed in the mandible (6 in premolar sites and 5 in molar sites) and 9 in maxilla (5 in premolar sites, and 4 in molar sites). Considering implant length, diameter, and position the distribution between the groups was similar (Table 1).

| Implant lenght/diameter (mm) | Group S Mandible 12 | Maxilla 8 | Group R Mandible 11 | Maxilla 9 |
|---|---|---|---|---|
| 9/3.8 | 1(P) | 2 (1P-1M) | 1 (P) | 2 (1P-1M) |
| 10.5/3.8 | 5 (4P-1M) | 2 (1P-1M) | 4 (3P-1M) | 3 (2P-1M) |
| 12/3.8 | 2(1P-1M) | 2 (1P-1M) | 2 (1P-1M) | 2 (1P-1M) |
| 9/4.6 | 1 (1M) | 1 (1M) | 1 (1M) | 2 (1P-1M) |
| 10.5/4.6 | 2 (1P-1M) | 1 (1M) | 1 (1M) | 0 |
| 12/4.6 | 1 (1P) | 0 | 2 (1P-1M) | 0 |
| S = no regenerated, R = regenerated, P = premolar area, M = molar area | | | | |

**Table 1.** Distribution between the groups of implants according to length, diameter, and position.

Follow-up examination: All patients were examined by one clnician (RG) at the baseline (implant placement), at the delivery of crowns (T1), at 1- (T2) and at 2-year (T3) follow-up. For data recording, at each test and each control implant the following clinical parameters were assessed: plaque index (PI), probing pocket depth (PPD) to the nearest millimeter at six sites around the implant, bleeding on probing (BOP) at six sites around the implant and width of the keratinized mucosa (KM) at the mid-buccal aspect of the implants.

Radiographic examination: Radiographs were taken using a film holder at the time of data collection by means of long cone technique. For the radiograph procedure, an individualized acrylic resin device was fixed to the residual dentition and a radiograph holder was constructed for each patient. This technique ensured that the same position of the radiograph film could be reproduced at each visit and the angle of the radiograph would not deviate. Radiographs were performed immediately at implant placement (baseline), at the delivery of definitive crowns (T1), and each year after loading (T2, T3). The radiographs were taken in high resolution mode (Vista Scan Durr Dental, Durr Dental S.r.l, Italy) with a dental x-ray machine (TM 2002 Planmeca Proline CC, Planmeca Group Helsinki, Finland), equipped with a long tube that operated at 70 Kw/7.5 mA.

Specialized software (Vista Scan Durr Dental, Durr Dental S.r.l, Italy) was used for linear measurements of marginal bone changes. The following radiographic measurements were performed: radiographic implant length (IL): distance (in mm) between the implant coronal margin and the implant apex as assessed at the mid portion of the implant; - residual bone height at the mesial (MI) and distal (DI) aspects of the implant: distance (in mm) between the line linking the coronal implant margin, and the first contact of the crestal bone on both mesial and distal sides of the implant.

To account for radiographic distortion, radiographic measurements on each radiograph were adjusted for a coefficient derived from the ratio: true length of the implant/IL. All measurements were carried out by a single trained examiner (RG) who had previously undergone a calibration session for radiographic assessment on a sample of 5 implants not included in the study (Kappa Test= 0.9640, SE of kappa = 0.06, 95% confidence interval: from 0.8792 to 1.000).

Statistical analysis: A public domain online software (Raosoft, http://www.raosoft.com/samplesize.html) was used to calculate the minimum number necessary for statistical evaluation. Data was analysed using a SPSS software (SPSS software version 13.0, Chicago, IL, USA). For clinical parameters (PD and REC) and radiographic MBL, data was calculated for each implant and reported as the mean ± SD, at baseline, at

crowns delivery (T1), at 1-year (T2), and at 2-year (T3) examination. Number of sites with plaque, and number of sites with bleeding at baseline, T1, T2, and T3, were also reported.

The normality of distribution of variables was controlled by the Kolmogorov–Smirnov test. Bonferroni test was used for multiple comparisons between two groups (S and R). The two-factor repeated measure ANOVA was used to compare variables between the groups at T1, T2, T3. Parametric test assumptions were not available for PI and BOP, thus, these variables were analysed with the Wilcoxon signed rank test. The results of Wilcoxon signed rank test were expressed as the number of observations (n) and the mean ± SD. An alpha error of 0.05 was set to accept a statistically significant difference. Student t-test was used to determine whether there was a statistically significant difference between MBL in the maxilla compared to the mandible, and in the patients without a history of periodontitis, compared with patients with a periodontal history now stabilized, among the separate groups.

## Results

The overall survival rate from baseline to the 2-year follow-up visit was 100% for both groups. Mean MBL values recorded at T1, T2, and T3 follow-up examination in S and R groups are reported in Table 2. At T1 examination the mean MBL in S group was 0.103 mm (±0.02), while in R group, it was 0.114 mm (±0.05). At T2 and T3 mean MBL values were 0.114 mm (±0.06), 0.118 mm (±0.07), and 0.124 mm (±0.04) and 0.131 (±0.03) mm, respectively for S and R group.

| | | T1 | T2 | T3 | Significance |
|---|---|---|---|---|---|
| S Group | N | 20 | 20 | 20 | |
| | Mean (mm) | 0.103 | 0.114 | 0.118 | 0.8046 |
| | SD (mm) | 0.02 | 0.06 | 0.07 | |
| R Group | N | | | 20 | |
| | Mean (mm) | 0.114 | 0.124 | 0.131 | 0.8927 |
| | SD (mm) | 0.05 | 0.04 | 0.03 | |
| Significance | | 0.8537 | 0.8162 | 0.7691 | |

(S= no regenerated; R= regenerated)

**Table 2.** MBL recorded during the follow-up examinations in both groups.

There were no significant differences between the groups when comparing peri-implant marginal bone–level changes at the different follow-up examination periods (p>0.05). Mean values of MBL of maxillary implants and mandibular implants are reported in table 3. The maxillary mean MBL values at T1, T2, and T3 examinations were 0.094 mm (±0.03), 0.102 mm (±0.02) and 0.126 mm (±0.04) respectively for the S group; and 0.103 mm (±0.04), 0.116 mm (±0.02) and 0.135 mm (±0.07), respectively for the R group. The mandibular mean MBL values at T1, T2, and T3 examination were 0.113 mm (±0.06), 0.121 mm (±0.01) and 0.128 mm (±0.03) respectively for the S group, and 0.123 mm (±0.06), 0.124 mm (0.04) and 0.136 mm (±0.03), respectively for the R group.

| S Group | Dental Arch | N | Mean (mm) | SD (mm) | Significance |
|---|---|---|---|---|---|
| T1 | Maxilla | 8 | 0.094 | 0.03 | 0.7538 |
| | Mandible | 12 | 0.113 | 0.06 | |
| T2 | Maxilla | 8 | 0.102 | 0.02 | 0.8017 |
| | Mandible | 12 | 0.121 | 0.01 | |
| T3 | Maxilla | 8 | 0.126 | 0.04 | 0.8532 |
| | Mandible | 12 | 0.128 | 0.03 | |
| R Group | Dental Arch | N | Mean | SD | Significance |
| T1 | Maxilla | 9 | 0.103 | 0.04 | 0.7893 |
| | Mandible | 11 | 0.123 | 0.06 | |
| T2 | Maxilla | 9 | 0.116 | 0.02 | 0.8842 |
| | Mandible | 11 | 0.124 | 0.04 | |
| T3 | Maxilla | 9 | 0.135 | 0.07 | 0.7987 |
| | Mandible | 11 | 0.136 | 0.03 | |
| Significance at T1 at T2 at T3 | | | 0.8649<br>0.7992<br>0.8144 | | |

(S= no regenerated; R= regenerated)

**Table 3.** Comparison of MBL in the maxilla vs. mandible in both groups.

| Group S | History of periodontitis | N | Mean (mm) | SD (mm) | Significance |
|---|---|---|---|---|---|
| T1 | + | 6 | 0.103 | 0.04 | 0.7648 |
| | - | 14 | 0.102 | 0.07 | |
| T2 | + | 6 | 0.116 | 0.05 | 0.9843 |
| | - | 14 | 0.111 | 0.02 | |
| T3 | + | 6 | 0.124 | 0.04 | 0.6895 |
| | - | 14 | 0.119 | 0.07 | |
| Group R | | | | | |
| T1 | + | 5 | 0.111 | 0.06 | 0.4987 |
| | - | 15 | 0.114 | 0.05 | |
| T2 | + | 5 | 0.131 | 0.02 | 0.6984 |
| | - | 15 | 0.128 | 0.07 | |
| T3 | + | 5 | 0.140 | 0.02 | 0.7374 |
| | + | 15 | 0.129 | 0.08 | |
| Significance at T1 at T2 at T3 | | | 0.7759<br>0.6981<br>0.8003 | | |

(S= no regenerated; R= regenerated)

**Table 4.** Comparison of MBL in patients with and without histories of periodontitis.

No statistically significant difference could be demonstrated between the two groups for implants placed in maxilla and mandible. In both groups, no statistically significant difference was noted for MBL between patients with a history of periodontitis stabilized and patients without periodontal histories (Table 3). Mean values of PI, BOP, PPD, and REC, recorded in both groups at the end of the follow-up period are reported in table 4. The mean plaque index values at the implant sites reached 21% (±12) for the S group, and 19% (±14) for the R group. In both groups, the mean BOP value reached 8% (±2.3), and 9% (±2.1), respectively, and the mean PPD value was 1.2 (±0.6) mm and 1.3 (±0.3) mm, respectively. The mean REC value recorded for the S group was 0.6±0.3 mm, and 0.5± 0.7mm for the R group. No significant differences between the two groups were noted for PI, BOP, PPD, and REC. (Table 5). In 89% of the sites in group S and 83% in group R, KM was present at the buccal aspect, with similar mean values in height [S group = 2.6 (±1.3) mm, R group = 2.8 (±1.1) mm)]. In both groups, no statistically significant differences were noted in MBL between sites with KTT >2mm and ≤2mm (Table 6).

| | PI (%) | | BOP (%) | | PPD (mm) | | REC (mm) | | KM (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Group | S | R | S | R | S | R | S | R | S | R |
| Mean | 21 | 19 | 8 | 9 | 1.2 | 1.3 | 0.6 | 0.5 | 2.6 | 2.8 |
| SD | 12 | 14 | 2.3 | 2.1 | 0.6 | 0.3 | 0.3 | 0.7 | 1.3 | 1.2 |
| Significance | 0.5748 | | 0.7943 | | 0.6783 | | 0.8137 | | 0.7892 | |

(S= no regenerated; R= regenerated)

**Table 5.** Results of the clinical measurements for implants in both groups.

| | KT | MBL | | |
|---|---|---|---|---|
| | | Mean (mm) | SD (mm) | Significance |
| Group S | >2mm = 6 implants | 0.124 | 0.11 | 0.7759 |
| | ≤2mm = 14 implants | 0.129 | 0.07 | |
| Group R | >2mm = 8 implants | 0.128 | 0.00 | 0.6981 |
| | ≤2mm = 12 implants | 0.141 | 0.02 | |
| Significance<br>≤2mm<br>>2mm | | 0.8003<br>0.7649 | | |

(S= no regenerated; R= regenerated)

**Table 6.** Comparison of MBL and KT in both groups.

## Discussion

In the present RCT, survival rates of implants placed in spontaneously healed extraction sockets versus treated extraction sockets showed no statistical difference. Moreover, results demonstrated that implants with laser-microtextured collars experienced minimal MBL when placed in regenerated and non-regenerated bone. The diversity of biomaterials and techniques used for extraction socket preservation makes it difficult to compare the results of the present study with previous publications. However, our findings are aligned with previously published data, indicating that dental implants placed in sockets preserved with various biomaterials, present clinical performance similar to implants placed into native bone. Barone et al.,[22] in a comparative study of implants placed in extraction sockets preserved with porcine-derived bone or spontaneously healed reported no significant difference in MBL between the two groups at 1 year, 2 years or 3 years.

Koutouzis and Lundgren[23] evaluated MBL around Implants placed in post-extraction sockets augmented with demineralized freeze-dried bone allograft (DFDBA) vs. no grafted extraction sockets. After 12 months of function, there was no significant difference in MBL between the groups. Quoc et al.[24] compared MBL at implants placed in alveolar sockets filled with DFDBA and platelet concentrates vs. implants placed in native bone. At 6 and 12 months, MBL around implants placed in sockets preserved with DFDBA and platelet concentrates was similar to MBL around implants placed in native bone. Similar results of MBL around implants placed in regenerated and native bone were reported also by Zitzmann et al.[25], Mayfield et al.[26] and Benić et al.[27] However, in the extraction sockets of these studies, grafting materials were used simultaneously with implant installation.

The values accepted as a reasonable guideline for MBL are 1.5 mm for the first year following loading of the implants and 0.2 mm of additional loss for each subsequent year. MBL represents an important indicator of peri-implant health, and the measure of its level is considered a determining factor in the evaluation of the quality of survival.[28]

In the present study, the mean MBL during the first, second and third year was 0.109 mm, 0.117 mm and 0.129 mm, respectively. In contrast to the proposed criterion of implant success, we observed less MBL over an average

of 3 years. The implant used in the present study has a 1.8 mm laser micro-grooved coronal design. In several studies, using implants with these collar features, showed minimal MBL. This has been explained by the capacity of laser-microgrooved collars to influence peri-implant soft-tissue response. Contrary to what has been shown in human histological data for implants with machined/smooth collars, laser-microgrooved implants exhibit perpendicular/functional orientation of connective tissue fibres around the implant collar allowing the protection of peri-implant bone.[29]

Results of present study showed no significant statistical difference between MBL around implants placed in patients with a history of periodontitis now stabilized, compared to implants placed in patients without periodontal history. This data is in contrast with what is reported by a recent literature review indicating that periodontally compromised patients may experience a higher MBL compared to non-periodontitis patients.[30]

However, the authors emphasized that the presence of uncontrolled confounding factors in the non-randomized studies included in the review, requires a precautionary assessment of outcomes. Moreover, according the results of a study of Fardal & Linden[31], who evaluated the implant failures in patients refractory to periodontal treatment during maintenance following ATP, it would seem that it is the presence of recurrent, rather than a history of periodontal disease which represents a risk factor for MBL. Given the small sample size and the short follow-up period of the present study, conclusions can not be drawn, and further studies with longer periods of observation with an increased number of implants are needed to evaluate if history of periodontitis could result in a greater predisposition to MBL around implants placed in preserved vs. no preserved extraction sockets.

Koutouzis and Lundgren[23] reported a statistically higher value of MBL around implants placed in previously preserved pluriradicular sites, compared to monoradicular sites, but not in those spontaneously healed. Since different percentages of residual graft material could influence the osseointegration process into regenerated extraction sockets, authors suggested that the difference in MBL might be attributed to greater dimension of pluriradicular extraction sockets when implants are more likely to be surrounded with graft particles at the coronal part of the osteotomy. In the current study, no significant differences were observed between the two groups for the amount of MBL around implants placed in premolar vs. molar sites, both in maxilla and in mandible. Compared to the study by Koutouzis and Lundgren, in which DFDBA was used as a grafting material, in the present study extraction sockets were grafted with porcine-derived bone. The chemical, physical and biological diversity of grafting biomaterials used could have influenced the different outcome of the present study. Bone samples harvested from regenerated extraction sockets of our patients showed a mean value of 16.57% (±3.8%) residual graft particles after six months.[24] Moreover, other histomorphometric analysis showed that remaining porcine-derived bone particles embedded in the vicinity of implants led to a normal bone to implant interface at the histologic level.[35,36] Based on these data, it is reasonable to postulate that, once the biomaterial particles are embedded in mineralized bone, they act similarly to the host bone, providing a biologic support to dental implants.

In both groups of the current study, no statistically significant differences were found in MBL between sites with KT >2mm and ≤2mm. Several clinical studies proved that mucosal tissues ≤2 mm in thickness may cause more MBL, while implants placed in thick tissues had significantly less MBL.[34-39] However, data on the influence of KT on peri-implant soft and hard tissue stability, summarized by two recent systematic reviews[40,41] are contradictory. The review by Suárez-López Del Amo et al.[40] states that there is sufficient evidence to conclude that implants placed in initially thinner vertical soft tissues have more radiographic marginal bone loss, while the review by Akcali et al.[41] failed to confirm superiority of thick over thin tissues in maintaining bone stability. Contrasting data may be related to the different considered follow-up period and to other potential confounding factors, such as, platform switching/standard design, cement-/screw-retained restoration and flapped/flapless surgical techniques, etc. Therefore, the dispute whether thick vertical soft tissues preserve more crestal bone stability still continues, and conclusions need further studies.

The limitations of the present study were the small sample size, the short follow-up period and the absence of a control group of implants without laser-microtextured collar.

## Conclusions

Within the limitations of this study, findings showed that, at the 24-month follow-up, implants with laser-microgrooved collar surface placed in regenerated extraction sockets and in native bone did not performed differently with respect to implant survival, MBL and peri- implant soft tissue parameters.

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## Declaration of Interest

Conflict of interest: Authors report no conflict of interest.

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