Influence of Prosthetic Parameters on Peri-Implant Bone Resorption in the First Year of Loading: A Multi-Factorial Analysis

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ABSTRACT

Background: The first year of prosthetic loading is crucial to peri-implant bone levels; however, contributing factors are yet barely understood.

Purpose: The purpose of the study is to investigate the influence of patient-, implant-, and prosthetic-related parameters on marginal bone resorption in partially edentulous patients within the first year of prosthetic loading.

Materials and Methods: This retrospective multifactorial analysis involved the following influencing factors: patient gender and age, implant diameter, implant location and neck design, insertion torque, insertion depth, splinted versus single-tooth restorations, crown height space, and crown-to-implant ratio.

Results: Mean peri-implant bone resorption around 200 dental implants was 0.98 ± 0.76 mm and significantly correlated to higher implant insertion depth ($p < .001$), whereas no association to prosthetic parameters could be observed.

Conclusions: Within the limits of the present analysis, it can be concluded that apical implant positioning may constitute a relevant determinant of early peri-implant bone resorption.

KEY WORDS: clinical study, crestal bone resorption, implant stability, implant surface, implant-supported crown, osseointegration, radiographs, tapered implants

INTRODUCTION

Although representing a surrogate outcome measure, peri-implant bone loss is considered an essential indicator for long-term dental implant success.[1] According to finite element analyses, occlusal stress predominantely affects the crestal area of peri-implant tissue[2]; however, marginal bone resorption has shown to be affected by a variety of patient-related factors, implant-related properties, as well as prosthetic characteristics.[3] The majority of marginal bone loss can be seen in the first year after implant placement,[4] yet bone healing in the crucial early phase of osseointegration is not completely understood. Aspects contributing to marginal bone loss around dental implants may involve surgical trauma, incorrect three-dimensional implant positioning, biologic width establishment, occlusal overloading, or nonaxial loading.[5–7]

From a biomechanical point of view, unfavorable loading conditions can be observed in implant-supported reconstructions showing higher lever arms or increased crown-to-implant ratios[8,9] and may differ substantially between single crowns and splinted implant restorations.[10] Thus, peri-implant bone loss may be attributed to structural adaptation of the bone to the

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applied force.[11,12] From a clinical point of view, reduced alveolar bone height may favor the placement of shorter implants to overcome the necessity of additional vertical augmentation procedures.[13] In this scenario, unfavorable crown-to-implant ratios with increasing stress–strain distributions at the crestal area may be observed in cases of off-axis loading.[6,14]

A number of prosthetic parameters are considered to affect dental implant outcome,[15–17] however, and have rarely been investigated together with other potential determinants of marginal bone resorption, such as implant neck designs,[18,19] insertion torque,[20] insertion depth,[21,22] and location of implant placement.[13,23] Thus, the aim of this study was to evaluate interactive effects of prosthetic parameters on peri-implant bone levels in the first year of loading in a multivariate analysis.

MATERIALS AND METHODS

Patients treated consecutively in a private practice in Vienna (Austria) in the years 2008 to 2011 were included in this retrospective analysis based on the following inclusion criteria: (1) partial edentulous patients; (2) sufficient bone width of at least 6 mm to allow dental implant placement without two-stage or simultaneous lateral bone augmentation procedures; (3) early implant placement 4 to 8 weeks after tooth extraction; (4) screw-retained single implant crowns or implant-supported fixed partial dentures; (5) prosthetic loading protocol following 4 to 6 weeks; (6) no provisionalization; (7) absence of mesial or distal cantilevers; (8) no evidence of occlusal overload due to bruxism;[24] and (9) regular occlusal relationship. The study protocol was approved by the local ethics committee (EK-Nr. 596/2011).

A standardized implant protocol respecting the manufacturer's recommendations was used for implant installation as well as fabrication of restorations. All implants (Nobel Replace™ Tapered, Nobel Biocare®, Göteborg, Sweden) were placed by the same surgeon (W.Z.). During low-speed insertion using a INTRAsurg 1000 surgical unit (KaVo, Bieberach, Germany), peak insertion torques were recorded. Flap elevation was performed by intrasulcular and crestal incisions without vertical releasing incisions. Implants were restored after a 4- to 6-week healing period using a standardized protocol without provisionalization. In esthetic sensitive areas of the anterior maxilla, patients wore removable prothesis with soft reliner without direct contact to the implant healing abutment. All implant-supported crowns were screw-retained directly to the implant.

Patients were instructed to use chlorhexidine mouthwash (0.2% Chlorhexamed, GlaxoSmithKline Pharma GmbH, Vienna, Austria) 2 days prior implant placement and for 1 week thereafter. Antibiotic prophylaxis (amoxicillin 875 mg and clavulanic acid 125 mg, Augmentin®, GlaxoSmithKline Pharma GmbH) was administered starting 1 day before surgery twice a day for 5 continuous days. In case of intolerance, clindamycin 300 mg three times per day (Dalacin® C, Pfizer Corporation Austria GmbH, Vienna, Austria) was prescribed. Mefenamic acid (Parkemed®, Pfizer Corporation Austria GmbH) or dexibuprofen (Seractil®, Gebro Pharma GmbH, Fieberbrunn, Austria) was used as analgesics. Clinical and radiological examination was performed at follow-up visits 1 year after prosthetic rehabilitation.

Radiological evaluation was performed at baseline (crown/bridge installation) as well as at follow-up visits. Marginal bone resorption considering individual magnification factors (determined by dividing radiographic implant length by actual implant length)[25,26] was computed twice at an interval of 4 weeks by two independent examiners (M.H. and N.Z.) to assess both intra as well as interexaminer variability. Implant insertion depth was evaluated as the vertical difference between implant shoulder and bone level. Crown height space was measured from the incisal edge to the marginal crest of the alveolar bone (Figure 1), and anatomical and clinical crown-to-implant ratios were calculated.[27] Anatomical crown-to-implant ratio was defined as the relationship between crown length and implant length. The relationship between crown height space and clinical fixture length was computed at baseline and used to evaluate the clinical crown-to-implant ratio (Figure 1).

Statistical Methods

Continuous data were described with mean ± standard deviation (SD) in case of normally distributed data and with median, minimum, maximum, lower, and upper quartile (interquartile range [IQR]) otherwise. For descriptive purposes, minimum, maximum, and/or lower and upper quartile were also used as additional description of normally distributed data. Categorical data were described with absolute and relative frequencies. A linear mixed model was used to assess effects of explanatory variables on marginal bone loss in

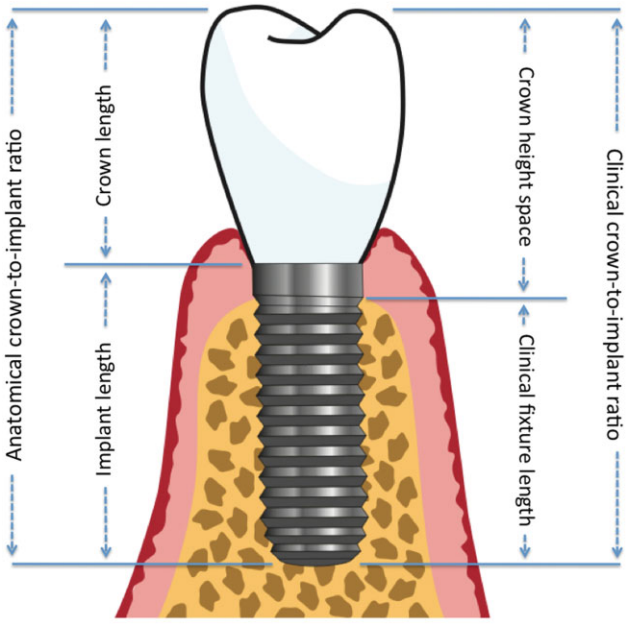

Figure 1 Schematic illustration of crown height space, anatomical, and clinical crown-to-implant ratio.

univariate and multiple models. Dependencies of multiple implants per patients were considered by a compound symmetry variance–covariance matrix for repeated values per patient. Residuals were graphically inspected to check assumptions of normally distributed residuals and homoscedasticity. Subgroups using medians as cutoff values were compared by Mann–Whitney *U* tests. Inter and intraobserver agreement for marginal bone loss was assessed by Bland–Altman graphs. Mean differences and 95% prediction intervals given in the graph were estimated by a linear regression. All *p* values are two sided and considered significant if ≤0.05. Statistical calculations were performed with the statistical software SAS® (Version 9.3; SAS Institute Inc., Cary, NC, USA).

RESULTS

A total of 200 implants in 103 patients (50 women, 53 men) were analyzed. Patient age at the time of implant surgery ranged between 21 and 77 years (median 55 years, IQR 44–65). One hundred one implants were placed in the upper jaw (51%), and 169 implants (85%) were placed in the posterior regions (premolars or molars). Implant lengths of 8 mm, 10 mm, 13 mm, and 16 mm were used in 3, 83, 111, and 3 cases, respectively. Mean crown height space measured 10.4 mm (median: 10.2; range: 5.8–16.0 mm; IQR: 9.1–11.7 mm), anatomical crown-to-implant ratio ranged between 0.48 to 1.53 (median 0.85; IQR 0.75–0.98), whereas clinical crown-to-implant ratios from 0.53 to 1.52 (mean: 0.93; median 0.89; IQR 0.77–1.06) were observed (Figure 2).

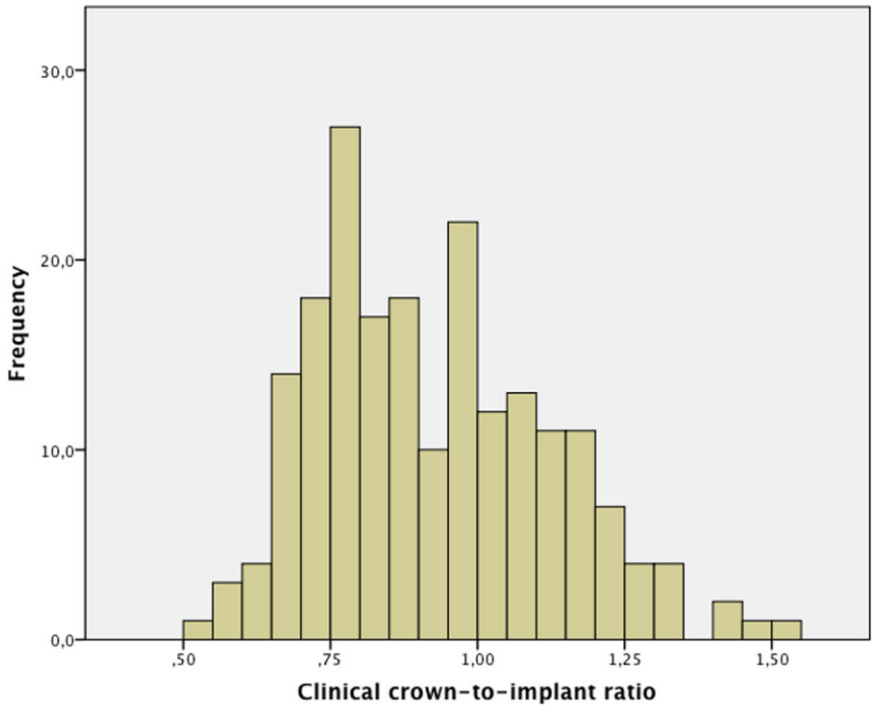

Figure 2 Histogram showing the distribution of clinical crown-to-implant ratios.

Implant diameters of 3.5 mm, 4.3 mm, and 5 mm were recorded in 16, 118, and 66 cases, respectively. Implant restorations included both single crowns ($n = 76$, 38%) as well as splinted crowns ($n = 124$, 62%). Implant neck modifications encompassed anodized ($n = 132$, 66%) and machined ($n = 68$, 34%) surfaces. Time between implant placement and follow-up visit was 18.6 months on average (median: 18 months; IQR 13–22 months; range: 10–30 months). Implant insertion depths variied from supercrestal (2.66 mm) to subcrestal positions (–1.21 mm; mean: 0.31 mm; median: 0.19 mm; IQR: –0.06 to 0.60 mm), whereas insertion torque values ranged from 15 to 60 Ncm (mean: 43.9 Ncm; median 45 Ncm; IQR 40–50 Ncm).

Mean peri-implant bone loss measured 0.98 ± 0.76 mm (range: –0.59 to 3.26 mm) and was not associated with anatomical ($p = .114$) or clinical crown-to-implant ratios ($p = .055$) in univariate testing. Bone loss was slightly higher around anterior implants compared with the posterior region (1.17 ± 0.13 mm vs 0.93 ± 0.06 mm; $p = .127$). Descriptive subgroup analysis of marginal bone loss according to patient-, implant-, and prosthetic-related factors (gender, age, location, neck design, insertion torque, insertion depth, type of prosthetic restoration, position, crown height space, anatomical, and clinical crown-to-implant ratio) is given in Table 1. Intra and interexaminer differences are visualized by Bland–Altman plots showing mean differences and 95% predictions intervals. Observed deviations between radiologic measurements are minor (Figure 3), whereas mean interexaminer deviations accounted for 0.02 ± 0.11 mm. The observed maximum deviation of inter and intraexaminer measurements was 0.30 mm and 0.55 mm, respectively.

Multiple regression analysis revealed no significant influence of patient-related factors, such as gender ($p = .135$) and patient age ($p = .617$), as well as implant-related factors, such as maxillary versus mandibular location ($p = .943$), machined versus anodized neck design ($p = .797$), implant diameter ($p = .268$), and

TABLE 1 Marginal Bone Loss Related to Patient, Implant, and Prosthetic Factors

			Number of Implants	Mean Marginal Bone Loss (SD)
Patient-related factors	Gender	Male	$n = 101$	0.94 (0.77)
		Female	$n = 99$	1.02 (0.75)
	Age	≤60 years*	$n = 104$	0.91 (0.69)
		>60 years*	$n = 96$	1.04 (0.78)
Implant-related factors	Location	Maxilla	$n = 101$	1.04 (0.76)
		Mandible	$n = 99$	0.93 (0.75)
	Neck design	Machined	$n = 68$	0.94 (0.87)
		Anodized	$n = 132$	1.00 (0.69)
	Insertion torque value	≤45 Ncm*	$n = 107$	1.04 (0.76)
		>45 Ncm*	$n = 93$	0.92 (0.75)
	Insertion depth	Supercrestal	$n = 139$	0.80 (0.73)†
		Subcrestal	$n = 61$	1.39 (0.64)†
Prosthetic-related factors	Type of prosthetic restoration	Single crown	$n = 76$	0.88 (0.71)
		Splinted	$n = 124$	1.05 (0.78)
	Position	Incisor/canine	$n = 31$	1.23 (0.68)
		(Pre)molar	$n = 169$	0.94 (0.76)
	Crown height space	≤10 mm*	$n = 89$	1.00 (0.72)
		>10 mm*	$n = 111$	0.96 (0.78)
	Anatomical crown-to-implant ratio	≤0.85*	$n = 102$	0.95 (0.74)
		>0.85*	$n = 98$	1.02 (0.78)
	Clinical crown-to-implant ratio	≤0.9*	$n = 104$	1.07 (0.71)
		>0.9*	$n = 96$	0.88 (0.79)

*Medians used as cutoff values for bipartite split.
†Indicating high statistical significance of $p < .001$.

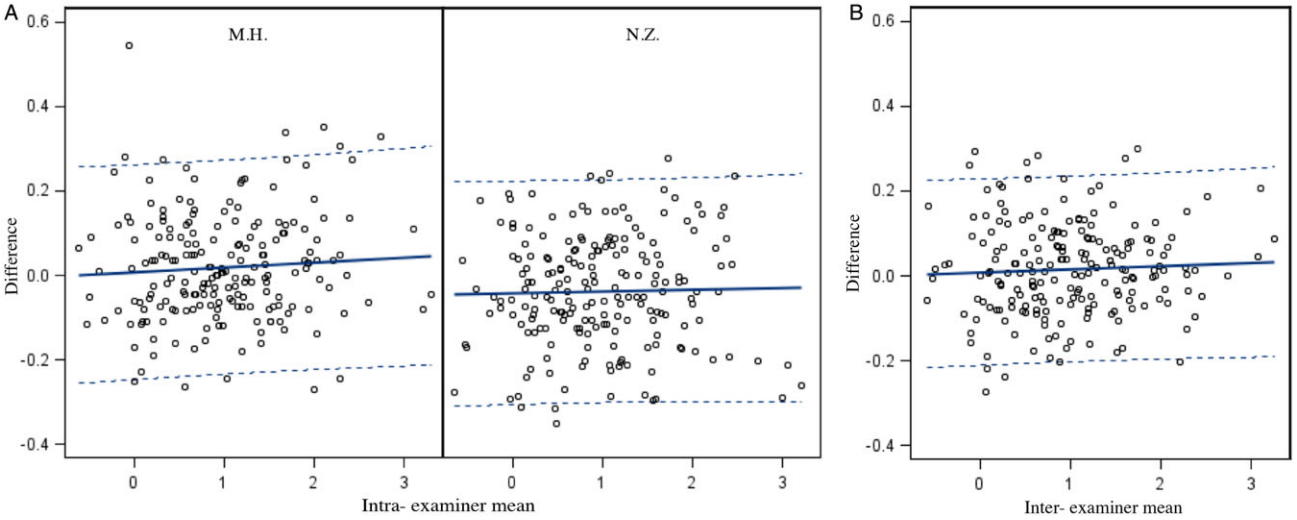

Figure 3 Bland–Altman plots to illustrate interexaminer (A) and intraexaminer (B) variability of marginal bone loss measurements (dashed lines indicating 95% prediction intervals).

implant insertion torque values ($p = .546$) on marginal bone loss. Insertion depth significantly influenced marginal bone resorption: deeper implant insertion depth resulted in increased peri-implant bone loss ($p < .001$). Among the prosthetic-related factors tested, no difference was observed between single crowns versus splinted restorations ($p = .722$) and anterior (incisors or canines) versus posterior (premolars or molars) implant positions ($p = .220$). Crown height space was not substantiated as an influencing factor ($p = .464$), and clinical crown-to-implant ratio had no significant effect on marginal bone loss ($p = .249$).

DISCUSSION

Results of the present study indicate that higher marginal bone loss may be attributable to subcrestal implant insertion. The importance of implant positioning is emphasized in several animal and clinical trials.[21,22,28,29] Bone remodeling occurs within 6 months following implant placement with relatively radiologically stable conditions afterwards.[22] Reasons for this bone resorption are yet barely understood but seem to be caused by bacteria contamination[30–32] and/or biologic width establishment.[33] By contrast, from a biomechanical point of view, strain levels at the bone crest might be reduced with increasing insertion depths.[34] However, all efforts should be put on optimizing implant positions as they determine subsequent peri-implant bone remodeling and prove to be the major determinant of bone loss in the present multifactorial analysis. This may especially become focus of attention in the esthetic zone where deeper implant installation has been demanded to guarantee proper emergence profile.[35,36] In these cases, special attention should be paid as peri-implant bone loss may signal the beginning of peri-implant soft-tissue collapse, thus, resulting in midfacial soft tissue recessions and/or discolorations. As peri-implant soft-tissue esthetics are becoming a scientific focus of interest, further studies would be valuable to investigate the impact of deeper implant insertion depths on peri-implant soft- and hard-tissue changes especially following immediate implant placement in a long-term observation.

This multifactorial analysis aimed to cover all relevant prosthetic factors from crown installation to follow-up of early-loaded implants. However, no information is available in the first 4 to 6 weeks following implant placement. Thus, there is a chance that bone level changes may have occured before implant loading because of insertion torque, insertion depth, or implant neck design. Considering the early loading protocol (4 to 6 weeks after implant placement), the risk may, however, be rather low. Our approach was to combine potential influencing factors assuming that a period of 4 weeks following implant placement would not be long enough to visualize radiological effects. Furthermore, it is currently unknown at which time point any effect of insertion torque or neck surface, for example, would be radiologically visible. It would be valuable for further prospective studies to separately investigate the impact

of factors from implant insertion to crown-installation as well as from crown-installation to follow-up. However, it remains questionable if it is possible to evaluate radiological effects in a separate analysis after 4 weeks already.

According to generally accepted biomechanical concepts, unfavorable crown-to-implant ratios are characterized through the presence of longer lever arms which determine the magnitude of strain at the fulcrum of an implant. If the applied forces exceed the critical threshold, bone resorption will be the result. However, in the present study, no statistically significant effect of crown-to-implant ratios was observed after the first year of functional loading which is in line with recent results from a retrospective study after 5 years of follow-up.[37] This may be possibly explained by the fact that crown-to-implant ratios did not reach the stress threshold level to imply peri-implant bone resorption. Other investigations, by contrast, found less crestal bone loss with higher crown-to-implant ratios,[27] contradictory to biomechanical concepts. The present study investigated the effect of different crown-to-implant ratios on marginal bone level in the first year of function, as reports on peri-implant bone loss should especially include the first year.[38] In other studies, by contrast, radiologic assessment started 1 year after implant placement[27] or after a mean healing time of 12 months.[37] Thus, this study adds relevant findings to existing knowledge concerning the early impact of differences in crown-to-implant ratio. It can be concluded that crown-to-implant ratio may not constitute a determinant of peri-implant bone loss in the first year of functional loading as well as following long-term results.

The majority of marginal bone loss occurs in the first year after implant placement.[4] Thus, the clinical crown-to-implant ratio rises with time to become more unfavorable as years go by. However, long-term marginal bone loss or late implant failure seems to be of different origin and prone to peri-implantitis or occlusal overload.[39] It is important to consider multiple factors together in assessing implant failure rates as interactive effects may be observed in the establishment and maintenance of osseointegration.[13,40] Thus, in the present study, attempts were made to control the relevant confounding variables (patient gender and age, implant location, implant diameter and neck design, insertion torque, insertion depth, splinted vs single-tooth restorations, crown height space, and crown-to-implant ratios) to investigate possible interactive effects of patient-based, implant-based, as well as prosthetic parameters on marginal bone resorption in partially edentulous patients within the first year of prosthetic loading. Because of the strict inclusion criteria, the present study results may only be applied in partially edentulous patients following early implant placement. Different results may be obtained in cases of immediate implant placement, after bone augmentation, in edentulous patients supporting a full-arch restoration, in cases of cantilever restorations, as well as in cases of cement-retained restorations. Thus, further studies are needed to gather more detailed information on possible interactive effects on marginal bone.

In assessing biomechanical-related detrimental effects on marginal bone level, the crown height space was proposed as a more significant indicator rather than the crown-to-implant ratio in cases of crown height spaces above 15-mm length.[6] In the present study, no influence of crown height space on crestal bone loss was observed; however, it has to be noticed that 99.5% of the restorations did not reach 15 mm in height. For each additional millimeter of crown height, stress concentrations at the implant neck may increase by 20%.[27] Interestingly, higher stress concentrations were observed in the buccal area around the implant neck with increasing crown height spaces[6] which may have an effect in the anterior maxilla: to overcome detrimental biomechanical effects of increasing implant crown heights with subsequent peri-implant bone loss as well as soft tissue impairment. Vertical augmentation procedures may be imperative to overcome the problem of higher implant-supported crown lengths.[26] In the present study, higher bone loss was observed in the anterior maxilla compared with the posterior area. This may be possibly explained by off-axis loading during remodeling process as occlusal loading was reported to contribute up to 71% to the total stress at the implant-bone interface.[17] Thus, attention should be paid to adequate reduction of nonaxial loading to decrease peri-implant stress as well as subsequent detrimental bone alterations.[41] Further studies are needed to evaluate the impact of stress magnitude especially in the anterior maxilla from a biomechanical and esthetic point of view.

Splinting of restorations was reported to compensate for detrimental effects of varying crown-to-implant ratios and crown height spaces by a better distribution of occlusal forces to decrease peri-implant stress.[14,42,43]

A comparative analysis of implant-supported fixed partial dentures (97.1%) and single-implant restorations (94.3%), however, revealed comparable success rates of 97.1 and 94.3%, respectively.[44] In the present study, no effect of splinting on crestal bone level was identified compared with implant-supported single tooth restorations. Similar results were observed in cases of different crown-to-implant ratios on marginal bone level.[27] By contrast, nonaxial force application in implant-supported splinted and unsplinted restorations seems to induce a significant increase of cervical stress[14] and might increase crestal bone loss.[45] Further research on the effect of splinted implant-supported restorations is needed especially in terms of force distribution at the implant-bone interface.

CONCLUSIONS

Within the limitations of the present study, it can be concluded that that higher marginal bone loss may be attributable to subcrestal implant positioning. Crown-to-implant ratios may not be considered as a confounding factor for peri-implant bone loss in the first year of functional loading as well as following long-term results.

CONFLICT OF INTEREST AND SOURCE OF FUNDING

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