Osseointegration of Oral Implants in Older and Younger Adults

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Osseointegration involves an osseous healing response that may be compromised by aging. This study aimed to test the hypothesis that there is no difference between older and younger adults in osseointegration success. A comparison was made between closely matched groups of 39 older adults who had 190 implants supporting 45 oral prostheses and 43 younger adults who had 184 implants supporting 45 oral prostheses. Patients were monitored for a period of 4 to 16 years after prosthetic loading. At the most recent follow-up, the cumulative implant success was 92.0% for the older group compared to 86.5% for the younger group. No statistical significance could be attributed to the difference in implant survival between the groups throughout the study period. Furthermore, the most common outcome for individual prosthetic sites was 100% implant success, and the original prosthetic design was maintained for as long as each patient was monitored in 41 of 45 prosthetic prescriptions for the older patients, and in 39 of 45 prescriptions for the younger patients.
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In the coming decades, older adults are expected to comprise a large proportion of individuals needing osseointegrated oral implants. People are living longer,[1,2] and missing teeth continue to be more prevalent in elders than in people of other age groups.[3,4] Traditional management of patients with missing teeth involves a variety of fixed or removable prostheses that are designed to exploit selected teeth and denture-bearing areas for support and stability. Despite optimal clinical efforts, the sequelae of such treatment sometimes include the recurrence of disease processes, tooth fracture, or residual ridge resorption, all of which may require further intervention to restore physiologic occlusion.[5–9] Many patients with removable prostheses also experience difficulty achieving comfortable and efficient function. Fortunately, maladaptive complete denture patients respond very well to implant prostheses.[10]

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Osseointegrated implants offer predictable and rigid anchorage of an alloplastic material in bone that can function prosthetically.[11] Implant prostheses seem particularly appropriate for the predicament of being elderly and edentulous.[12] However, the specific merits of osseointegration in elders have been extrapolated mainly from the experiences of middle-aged patients. Furthermore, osseointegration is dependent on a wound-healing response that could be altered by aging, as evidenced by the relationship between age and osteoporosis,[13,14] and by reports that wound healing may be compromised in older individuals.[15] Thus, it cannot be assumed that osseointegrated oral implants will be equally successful in individuals from all age groups.

To date, five studies[12,16–19] have compared oral implant outcomes in older and younger adults (Table 1). They document a 94 to 97% range of implant success among older patients and an 88 to 99% range of success among younger patients. While encouraging, these results must be considered in the context of their very short minimum follow-up periods. However, a more serious threat to their validity is the absence of a matched control group of younger adults. Only Kondell et al[16] report similarity in both gender and prosthetic designs between test and control groups. Otherwise, few comparisons were made

Table 1 Studies Reporting Implant Success in Older Versus Younger Adults

		Older group		Younger group	
	Loading period (y)	Age (y)	% Success (no. of implants)	Age (y)	% Success (no. of implants)
Kondell et al[16]	1–6	≥ 65	97 (284)	< 55	93 (183)
Bass and Triplett[17]	< 1–6	> 60	94–96 (?)	≤ 60	97–99 (?)
Jemt[18]	1–4	80–90	96 (208)	—	—
Zarb and Schmitt[12]	1–12	65–81	96 (74)	28–69	88 (274)
Ochi et al[19]	0	≥ 60	97 (1216)	< 60	97 (916)

between the groups with respect to the diversity of gender, implant length, site and number, prosthetic design, occlusal loading considerations, systemic health, smoking behavior, and jawbone quantity and quality. It is hypothetically possible, for example, that the older groups had a relatively larger number of edentulous patients with implants placed in the anterior part of the mandible, a treatment design that has yielded very successful outcomes.[20,21] Consequently, the reported level of success in the older adults may have been favored on a site-specific basis, potentially hiding an age-specific difference.

This report forms part of an ongoing investigation to document the clinical effectiveness of diverse prosthodontic applications of the Brånemark implant system. This study tested the hypothesis that there is no difference between older and younger adults in the clinical osseointegration success of oral implants. The study compared an older (test) group with a younger (control) group on the basis of the cumulative probability of survival of oral implants retained in function.

Materials and Methods

Forty-six consecutively treated partially or completely edentulous older adults (at least 60 years of age) had oral implant placement (stage one) in the Implant Prosthodontic Unit (IPU) of the University of Toronto between 1980 and 1992. Fifty-three prostheses were planned for these patients. The completely edentulous patients consented to receive implant prostheses because of persistent maladaptation to wearing dentures, related primarily to a lack of prosthesis stability as elaborated by Zarb and Schmitt.[10] Several of the partially edentulous patients had similar difficulties with removable prostheses. More commonly, however, implants were favored in these patients because the outcome of traditional therapy was considered to be relatively more risky, particularly where potential abutment teeth were healthy and unrestored. Patients were excluded if they had a systemic health problem that precluded a minor surgical procedure, a lack of bone volume to accommodate an implant of at least 7 mm long and 3.75 mm wide, a history of major jaw surgery or head and neck radiation, a history of drug abuse or psychosis, or cosmetic expectations that could not be satisfied with a pretreatment tooth arrangement or optimized denture.

It was intended that each of the prostheses planned for these patients would be paired, in order of implant placement, with the first available match to a prosthesis planned in younger patients (less than 50 years of age) also treated consecutively in the IPU during the same period. Paired matching of prosthetic plans was attempted on the basis of gender, prosthetic design, implant number and location, year of stage-one surgery, and status of the opposing dentition. In several situations, however, it was not possible to obtain an exact match for implant number, year of stage-one surgery, or status of the opposing dentition. For example, a deviation of one implant per pair of prostheses was considered an acceptable match, yielding a slightly unequal number of implants per group. Matching was not possible for eight prostheses planned in seven of the older patients, so these patients were eliminated from the study.

The test group included 39 older adults with 190 Brånemark implants (Nobel Biocare, Göteborg, Sweden) placed to support 45 prostheses; the control group included 43 younger adults with 184 Brånemark implants placed to support 45 prostheses. At stage one, the older group ranged from 60 to 74 years of age (mean 66 years), compared to a range of 26 to 49 years (mean 41 years) for the younger group. The matching procedure permitted the groups to be identical in terms of gender, implant location, and prosthetic plan. In this regard, 64% of the matched plans in both groups involved female patients. In both groups, 84% of the matched prosthetic sites involved zone I implants (at or anterior to a vertical line through the mental foramina). The remaining sites in both groups involved zone II implants (posterior to zone I), all of which were used to support fixed par-

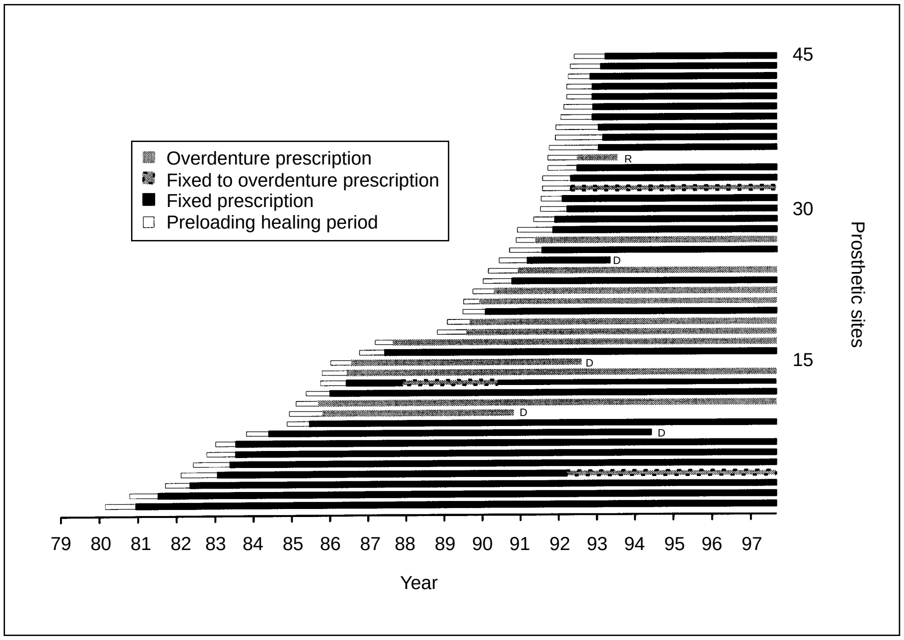

Fig 1 Older group follow-up of implant loading period by prosthetic site. D = deceased patient; R = removal of all remaining implants.

Table 2 Matched Prosthetic Plan at Stage One for Both Younger and Older Groups

	Maxilla	Mandible	Total (%)
Complete fixed	6	17	23 (51)
Complete overdenture	1	11	12 (27)
Partial fixed	5	3	8 (18)
Single tooth	2	0	2 (4)
Prostheses planned	14 (31%)	31 (69%)	45

tial prostheses. In both groups, 78% of the matched prosthetic plans involved completely edentulous arches, and 69% involved the mandible (Table 2). The complete fixed sites had an average of five or six implants placed, compared to an average of two or three implants for overdenture and partial prosthesis sites. The single-tooth sites each had one implant placed. The matching procedure also permitted similarity in the opposing dentitions between the groups. The older group had 26 sites opposed by a complete denture, whereas the younger group had 23 such sites. Both groups had 15 sites opposed by natural teeth or fixed prostheses, and the remaining sites were opposed by either tooth- or implant-supported removable prostheses.

The groups also demonstrated similarity relating to variables not involved in the matching procedure. Over 75% of the implants in both groups were 10 or 13 mm in length, while only 2% were less than 10 mm. Using the classification system proposed by Lekholm and Zarb[22] (with the A to E scale assigned values 1 to 5, respectively), both groups demonstrated a mean preoperative bone quality of about 2.5, and a mean preoperative bone quantity of about 2.7. Chronic smoking behavior was reported by slightly less than 20 percent of the patients in both groups. Not surprisingly, the average health of the groups differed somewhat, suggesting better health among the younger patients. The potential influence of these variables will be reported separately based on a multivariate analysis.

The implants were uncovered surgically (stage two) after a healing period of 4 to 6 months, followed by prosthetic loading an average of 10 months (5 to 25 months) after stage-one surgery (Figs 1 and 2). For the fixed prostheses, transmucosal abutments were used to retain a rigid metal substructure on which acrylic resin teeth were processed in the case

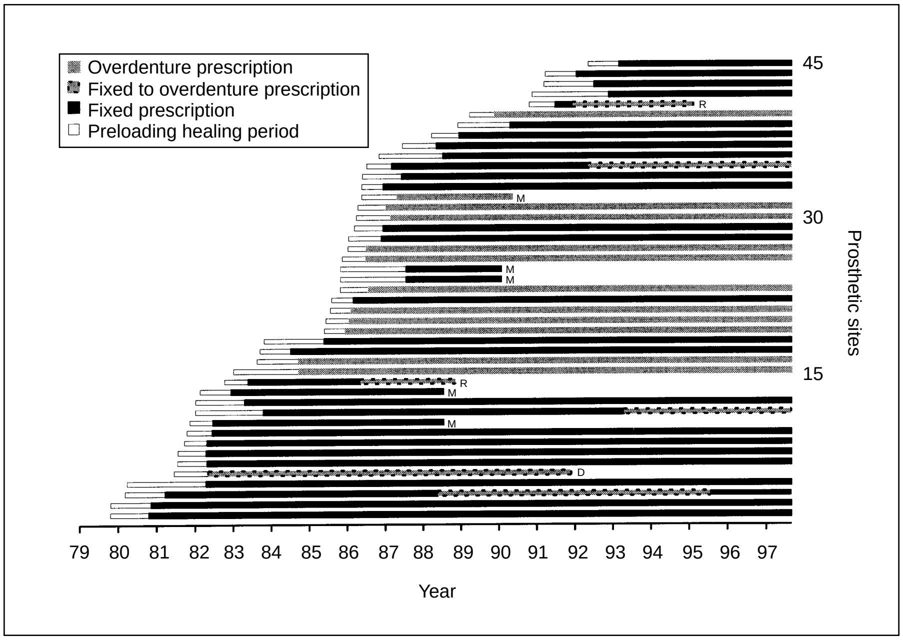

Fig 2 Younger group follow-up of implant loading period by prosthetic site. M = migration of patient; D = deceased patient; R = removal of all remaining implants.

of large prostheses or porcelain was baked in the case of small fixed partial dentures or single crowns. For the overdentures, transmucosal abutments generally were used to retain a Dolder bar, which in turn permitted denture retention via a metal clip.

Regular, usually annual, follow-up examinations included clinical and radiographic assessment of individual implants with the prostheses removed, as recommended by Albrektsson et al[23] and Albrektsson and Zarb.[24] Implants demonstrating clinical mobility were removed and recorded as failed. For purposes of statistical testing, cumulative survival curves, with standard error calculations, were developed for both patient groups based on the probability of implant survival at the midpoint of each yearly interval. The grouped survival data were tested for significant differences over the entire period of observation using the LIFETEST procedure of the SAS statistical software (SAS Institute, Cary, NC). Specifically, both the log rank and Wilcoxon's tests were applied, since they are both appropriate for testing homogeneity of survival curves involving censored data, as in this study, where follow-up periods vary between subjects.[25]

Results

Prior to prosthetic loading, ie, at stage two, the older group had 9 original implants removed because of lack of osseointegration, compared to 14 in the younger group (Tables 3 and 4). These implants demonstrated clinical mobility that was often corroborated by a radiolucent space at the implant-bone interface. In a limited number of sites, implants had to be "put to sleep," ie, left unconnected to the prosthesis, because they could not be used prosthetically. Both groups had two such implants at stage two. These implants, along with the implants lost to follow-up because of patient migration or death, were censored from further assessment. Implants placed to compensate for losses were not included in the calculation of cumulative implant survival. At the time of prosthesis placement, the older patients had 179 original implants loaded, compared to 168 plus 2 of 3 replacement implants in the younger group. By that time, the probability of survival of the original implants was 95.2% among the older group and 92.3% among the younger group (Tables 3 and 4).

Implants Retained in Function. Follow-up examinations were conducted over an average of 8 years for the older group and 10 years for the younger group (Figs 1 and 2). At the most recent follow-up, at least 4 years had passed since prosthetic loading for all of the patients, and 10 years had passed for over 50% of the patients. By the end of the fourth year of loading, one older patient had died, censoring five original implants from further follow-up, and two older patients each had one additional implant "put to sleep," also censoring them from further follow-up. The migration of two

Table 3 Older Group Cumulative Implant Success

Time period	Implants entering period	Censored implants: Patient death or migration	Censored implants: Put to sleep	Implants available for calculation	Implants failed	Interval success rate (%)	Cumulative success rate (%)
Insert to load	190	0	2	188	9	95.2	95.2
Load to 2 years	179	0	2	177	5	97.2	92.5
2 to 4 years	172	5	0	167	1	99.4	92.0
4 to 6 years	166	3	0	78	0	100.0	92.0
6 to 8 years	78	2	0	56	0	100.0	92.0
8 to 10 years	56	0	0	56	0	100.0	92.0
10 to 12 years	56	5	0	34	0	100.0	92.0
12 to 14 years	34	0	0	18	0	100.0	92.0
14 to 16 years	18	0	0	4	0	100.0	92.0

Table 4 Younger Group Cumulative Implant Success

Time period	Implants entering period	Censored implants: Patient death or migration	Censored implants: Put to sleep	Implants available for calculation	Implants failed	Interval success rate (%)	Cumulative success rate (%)
Insert to load	184	0	2	182	14	92.3	92.3
Load to 2 years	168	0	0	168	7	95.8	88.5
2 to 4 years	161	7	0	154	1	99.4	87.9
4 to 6 years	153	4	1	129	2	98.4	86.5
6 to 8 years	127	6	0	111	0	100.0	86.5
8 to 10 years	111	3	1	94	0	100.0	86.5
10 to 12 years	97	0	0	63	0	100.0	86.5
12 to 14 years	63	0	0	44	0	100.0	86.5
14 to 16 years	44	0	0	15	0	100.0	86.5

younger patients censored an additional seven implants from follow-up in the interim. Among the older patients, six original implants failed and were removed during this period, compared to eight failures recorded among the younger patients, including one osseointegrated implant that had to be removed at the patient's insistence.

The patients assessed at the end of the 10th year since loading included 15 older patients who had 64 implants placed originally in 15 prosthetic sites, and 27 younger patients who had 107 implants placed originally in 28 prosthetic sites. Although fewer older than younger patients had been followed to the 10-year mark, there is certainly validity in the exercise of comparing the groups up to at least this point, since a large majority of implant failures were recorded very early in the follow-up periods (Tables 3 and 4), and the groups remained very similar at the 10-year point regarding potentially confounding factors. For instance, females made up just over 80% of both groups at this point. Eight of every 10 sites at the 10-year mark involved the mandible in both groups, and the proportion of prosthetic plans also remained similar. The average preoperative bone quality per site was about 2.2 in both groups, and the average preoperative bone quantity per site was about 3.0 in both groups. The distribution of original implant lengths was also comparable, with 10- or 13-mm implants accounting for 9 of every 10 implants in both groups. As suggested, the potential influence of these factors will be examined by means of a multivariate analysis, which will be reported separately, whereas the emphasis of this report has been on isolating the potential influence of age on implant outcomes.

At the most recent follow-up, between 4 and 16 years had passed since implant loading (Figs 1 and 2). A majority of patients continued to be available for follow-up of their implant prostheses. Among them were 35 older patients with 156 original and 2 replacement implants supporting 40 prostheses, and 36 younger patients with 136 original and 4 replacement implants supporting 37 prostheses. In total, the deaths of 4 older patients censored 15 implants from follow-up at various times during the study, while the migration or death of 5 younger patients censored 20 original implants from follow-up (Tables 3 and 4). In

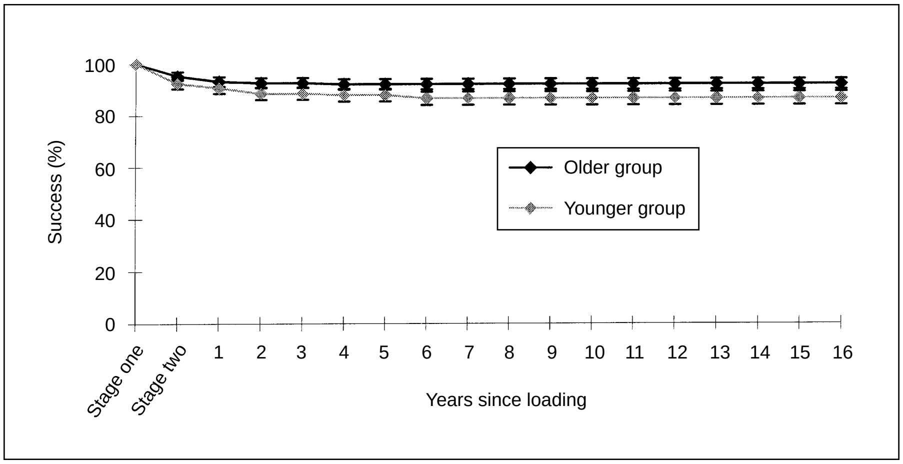

Fig 3 Cumulative implant survival, with error bars, for older and younger groups. No significant difference between curves was found using log rank and Wilcoxon's statistics.

total, both groups also had 4 original implants "put to sleep." Cumulative survival of the original implants during the entire period was 92.0% among the older group and 86.5% among the younger group (Tables 3 and 4), and the majority of failures occurred by the end of the first year after stage two. Statistical significance could not be attributed to the differences found between the survival curves (Fig 3) as determined by either Wilcoxon's signed rank or the log rank tests, even at the $P < .10$ significance level. Preliminary radiographic analysis of the completely edentulous patients in this study suggested that the mean annual rate of bone resorption proximal to the implants in both groups was less than 0.05 mm. Detailed radiographic analysis will be reported separately.

Follow-up by Prosthetic Site. The period of follow-up by prosthetic site is shown in Figs 1 and 2. Of interest, the original prosthetic plan was maintained for as long as each patient was monitored in 41 of 45 older patient prescriptions and in 39 of 45 younger patient prescriptions. The older group had two mandibular complete fixed prostheses, which had to be switched to an overdenture design because of implant failures in one site and repeated screw fractures in the other. A similar interruption in a fixed partial denture site in the older group was soon resolved with a new fixed prosthesis supported in part by replacement implants. The older group also included one maxillary overdenture patient who eventually lost all four implants, necessitating a conventional complete denture. The younger group had six complete fixed prostheses that had be switched to overdentures as a result of either failed implants or repeated screw fractures. Among these patients, one maxillary site and one mandibular site eventually lost all implants, necessitating complete denture treatment. Another of these patients was switched to an overdenture because of screw fractures apparently from a clenching habit, but she was successfully switched back to the original prosthesis once the parafunction subsided. It should also be noted that 100% implant success was the most common outcome for individual prosthetic sites for the duration of follow-up. Among the older group, an implant was either removed or "put to sleep" in only 13 of the 45 sites, compared to 12 of 45 sites in the younger group.

Discussion

It is increasingly evident that osseointegrated oral implants can be used in diverse prosthodontic applications. Predictability of implant-supported prostheses relies on the time-dependent integrity of osseointegration. The major criteria for clinical osseointegration success are immobility of individual implants accompanied by lack of radiolucency, pathology, and crestal bone loss.[23] Based on these criteria, the osseointegration of Brånemark implants in this study was equally successful in older as in younger adults. This observation is based on patients followed over 4 to 16 years since prosthetic loading. It is unlikely that a true age-specific difference was overlooked since, with the exception of health problems, the test and control groups were very similar with respect to all potential confounding factors mentioned in the introduction. Although speculative, it would not be surprising if the older group also had more undiagnosed disease states including osteoporosis. That more health problems were reported among the older group suggests that osseointegration success may be unaffected by the common illnesses associated with aging. Indeed, although not statistically significant, the results suggest a tendency for better success among older patients.

Three questions have been posed in relation to the prosthodontic treatment of geriatric patients in the context of osseointegration:[26]

1. Can osseointegrated implants be prescribed for elderly patients?
2. Can successful osseointegration be maintained as patients age?
3. Can the principles of osseointegration be reconciled with different prosthodontic techniques to facilitate treatment accessibility to geriatric patients?

This study suggests an affirmative answer to all three of these questions.

First, it appears that age alone should not be used to exclude patients from being prescribed oral implants. In total, the older group required the removal of 15 of the original 190 implants, compared to 24 of 184 for the younger group. Assuming adherence to established surgical and prosthetic protocols, it appears that oral implants can be equally successful in older and younger adults. As expected, the elderly patients in this study exhibited more systemic health problems than the younger patients. Nonetheless, routine surgical precautions provided safe and successful outcomes regardless of age.

Second, it appears that osseointegrated implants can be maintained as patients age, even in older patients as they become increasingly debilitated. The majority of implant failures in this study occurred in the period prior to loading or during the first year after loading in both age cohorts. During the course of the study, the average age of the younger group increased from 41 to 51 years, while the age of the older group increased from 66 to 74 years. A number of older patients were able to enjoy their prostheses well into their ninth decade of life despite a decline in their ability to maintain optimal oral hygiene. As noted, the original prosthetic plan was sustained over the study period for most of the younger and older patients. Furthermore, the mean annual loss of crestal bone proximal to the implants was minimal in both groups.

Finally, osseointegration appears to lend itself to a diversity of prosthodontic applications equally well in both younger and older adults. This study involved relatively few partially edentulous adults, so more investigations are needed to ascertain the significance of age in the treatment of a variety of these cases. More conclusively, it appears that osseointegration can be maintained using either fixed or removable prostheses in completely edentulous adults, regardless of age. However, it has yet to be determined which of these prescriptions might be preferable in the patient for whom either option is feasible. Hemmings et al[27] found that, in the short-term, fixed complete prostheses required more frequent maintenance than removable overdentures. Others[28,29] have contradicted this, suggesting that further studies are needed to clarify the issue and to establish the long-term cost benefit of fixed versus removable options to enable improved treatment decisions and advice to patients.

Conclusion

Elders should expect osseointegration success no different from that seen in younger adults. Additional studies are needed to supplement this conclusion in the context of a diversity of jaw sites and prosthetic applications in both partially and completely edentulous adults. The implications of oral implant use in growing adolescents cannot be extrapolated from these results. All oral implant patients should be advised of a small but important risk that implant or prosthetic failure may necessitate treatment revision with an implant overdenture or a traditional removable denture replacement. For this reason, treatment planning should stress implant options only when the outcome of traditional prosthodontic therapies is considered to be relatively unfavorable. This may be particularly apropos for elderly patients whose denture-wearing complaints may very well be resolved by new conventional dentures.

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