The influence of crown-to-implant ratio on marginal bone loss: a narrative review

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Abstract: Marginal bone loss (MBL) is considered a fundamental criterion for implant success. Many factors may influence MBL, but it is still not clear how MBL is influenced by crown-to-implant ratio (C/I-R). In addition, the introduction of short implants, to avoid bone augmentation procedure, lead to ratios higher and higher. The aim of this study is to elucidate about the role of high C/I-R on MBL. The articles were identified through MEDLINE database (via PubMed) and checking references. After the selection, 20 articles were included in the review. The highest follow-up among the selected studies was 16 years for the retrospective studies and 5 years for the perspective studies. The highest ratio reported was 2.53. In conclusion, is possible to state that C/I-R not exceed 2.2 did not influence the manifestation of biological complications and lead to a not significant MBL.

Keywords: Crown-to-implant ratio (C/I-R); marginal bone loss (MBL); short implants

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Introduction

Dental implants are considered nowadays a reliable solution to replace teeth. High implants and prosthesis survival rates (above 98% after 5 years) were achieved (1,2). To consider successful an implant therapy the criteria at implant level are: absence of pain, bone loss at 1st year <1.5 mm, annual bone loss <0.2 mm thereafter, no radiolucency, no mobility, no infection (3). Therefore, marginal bone loss (MBL) represents a favourable factor for long-term implant stability (4). Unfavourable crown-to-implant ratio (C/I-R), occlusal overload, occlusal table width, off-axis loading and cantilevers are factors that play a role in the failure of prosthetic implant therapy (5-7). The influence of cantilever (8), occlusal overload (9), and off-axis loading in prosthetic complications are largely demonstrated.

However, the role of C/I-R on MBL is still unclear. C/I-R is the application in implantology of the prosthodontics parameter of crown-to-root ratio. Ideally, the ratio between the crown and the root should be 1:2, and a minimum of 1:1 for a tooth abutment is recommended. To avoid unfavourable C/I-R, these prosthetic concepts have been used in implant dentistry. C/I-R is calculated as the ratio between the crown and implant lengths. We can distinguish two different C/I-R:

- ❖ Anatomical ratio is the ratio between the distance from the apex to the shoulder of the implant, and the distance from the shoulder of the implant to the end of the crown;
- ❖ Clinical ratio is the ratio between the distance from the apex to the bone level, and the distance from the bone level to the end of the crown.

In literature there are evidences that attest both the presence (10) and the absence (11,12) of a relationship between MBL and C/I-R, and one studies even deducted that high CI might provide a protective effect on bone

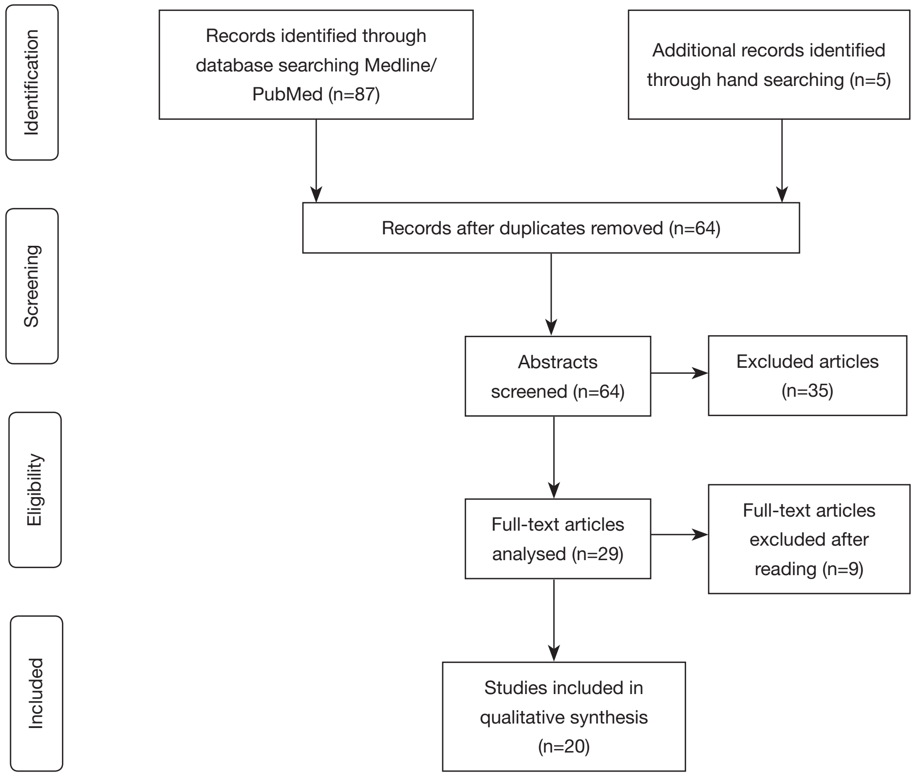

Figure 1 Flowchart of study selection.

loss (13). In addition, the introduction of short implant, to avoid bone augmentation procedure, lead to C/I-R higher and higher. A security threshold should be investigated to avoid biological complication and to guarantee the success of the therapy. The aim of this study is to elucidate about the role of C/I-R on MBL. We present the following article in accordance with the Narrative Review reporting checklist (available as http://dx.doi.org/10.21037/fomm-20-57).

Methods

The articles were identified through MEDLINE database (via PubMed) combined the key words: "crown-implant ratio", "marginal bone loss", "alveolar bone loss", "short implants". The search was supplemented checking references of the relevant review articles. The studies had to meet the following requirement:

- ❖ At least 1 year follow-up;
- ❖ Mean C-I/R should be reported;
- ❖ Outcome measures should include at least bone changes;
- ❖ Publication must be reporting in the English.

The selection path of the articles is shown in *Figure 1*.

Discussion/summary

The primary selection identified 87 studies for the MEDLINE search. Checking of relevant reviews revealed five additional articles that met the inclusion criteria. After having removed duplicates and analysed titles and abstracts, 58 studies were excluded because they did not meet the inclusion criteria. The remaining 29 papers were evaluated by full-text analysis. Nine articles were finally excluded after full-text reading due to lack of information as marginal bone changes and C/I-R measurement. Characteristics of the selected studies are shown in *Tables 1* and *2*. Anitua *et al.* (14) in a retrospective study analysed 45 implants with a mean C/I-R of 2.4. The mean MBL reported was 1.01 mm for mesial bone, 0.89 mm for distal bone. Birdi *et al.* (15) studied 309 implants in a retrospective study. The mean C/I-R reported was 2.0 and the MBL was 0.2 mm. Blanes *et al.* (16) in a perspective study analyzed 109 implants. The mean C/I-R was 1.77. MBL was calculated for three different groups: group A (C/I-R 0–0.99): 0.35 mm, group

Table 1 Studies included in the review

Article	Years of publication	C/I-R considered	Mean C/I-R	Mean CHS	Survival rate	Marginal bone changes
Anitua *et al.*	2014	Clinical	2.4 (1.5 to 3.69)	17.05±3.05 mm (11.2 to 25.4 mm)	100%	Mesial bone loss 1.01±0.68 mm (range 0 to 3.49 mm); distal bone loss 0.89±0.7 mm (range 0 to 3.86 mm)
Birdi *et al.*	2010	Clinical	2.0 ±0.4 (0.92–3.2)	13.3±2.6 mm (6.2–21.7)	–	Mesial: −0.2±0.7 mm; distal: −0.2±0.9 mm
Blanes *et al.*	2007	Clinical	1.77±0.56 mm	Anatomical crown length: 9.57±2.6 mm; clinical crown length: 13.57±2.73 mm	Group ratio >2 mm: 94.1%	Group A (C/I-R: 0–0.99): −0.35±0.27 mm; Group B (C/I-R: 1–1.99): −0.03±0.15 mm; Group C (C/I-R >2): −0.02±0.26 mm
Di Fiore *et al.*	2019	Clinical	2.21±0.31 mm	10.86±0.99 mm	–	−1.42±0.38 mm
Guljé *et al.*	2016	Clinical	2.14±0.42 (1.16 to 3.23)	–	100%	−0.13±0.36 mm
Hadzik *et al.*	2018	Anatomical	1.69	–	–	−0.34±0.24 mm
Hingsammer *et al.*	2017	Clinical	1.70 (SD: 0.48)	9.9 mm (SD: 1.24 mm; range: 8.1–12.4 mm)	97.3%	−0.71 mm (SD: 0.74 mm)
Lee *et al.*	2012	Clinical	1.06±0.42	–	–	−0.93±0.15 mm (range, 0.05 to 1.89 mm)
Malchiodi *et al.*	2014	Clinical and anatomical	Anatomical: 1.84±0.65 (range: 0.86–4.28); Clinical: 2.08±0.80 (range: 0.95–4.80)	–	98.1%	−0.48±0.29 mm
Mangano *et al.*	2016	Clinical	1.70 (0.25; median 1.72; range 1.40–2.25; 95% CI: 1.65–1.75).	–	97%	C/I-R <2: 0.38 mm; C/I-R >2: 0.48 mm
Naenni *et al.*	2018	Anatomical	6-mm group: 1.75 (IQR, 1.50 to 1.90); 10-mm group: 1.04 (IQR, 0.95 to 1.15)	–	6-mm group: 91% (95% confidence interval: 0.836 to 0.998); 10-mm group: 100%	6-mm group: −0.29 mm (IQR, −0.92 to 0.23); 10-mm group: −0.15 mm (IQR, −0.93 to 0.41)
Nunes *et al.*	2016	Clinical	2.53±0.79	12.7 mm (range 11.94 to 19.99)	100%	−0.67±0.63 mm
Pieri *et al.*	2012	Clinical	1.94 ±0.46 (range 1.31 to 3.12)	11.16±2.72 mm (range 7.42 to 17.34)	96.8%	−0.60±0.13 mm
Ramaglia *et al.*	2019	Anatomical	1.08 (C/I-R minimum value =0.58; C/I-R maximum value =2.25)	–	100%	C/I-R ≤1: −0.653±0.58 mm; C/I-R >1: −0.287±0.26 mm

Table 1 (*continued*)

Table 1 (*continued*)

Article	Years of publication	C/I-R considered	Mean C/I-R	Mean CHS	Survival rate	Marginal bone changes
Rossi *et al.*	2016	Clinical	Test: 1.55 (1.02 to 2.53); Control: 0.97 (0.58 to 1.40)	Test: 7.7± 2.0 mm (4.5 to 12 mm); Control: 7.3± 1.9 mm (4.6 to 11 mm)	Test: 86.7%; Control: 96.7%	Between the surgery and prosthesis delivery: Test: −0.38 mm; Control: −0.36 mm. After 5-year: Test: −0.14 mm; Control: −0.18 mm
Schneider *et al.*	2012	Clinical and anatomical	Anatomical: 1.04±0.26 (0.59 to 2.01); Clinical: 148±0.42 (0.82 to 3.24)	–	95.8%	−0.008 mm (SD 0.74 mm)
Sharmann *et al.*	2016	Clinical	Test: 1.48±0.33; Control: 0.86±0.18	–	Test 98%; Control 100%	Test: −0.19±0.62 mm; Control: −0.33±0.71 mm
Urdaneta	2010	Clinical	1.6 (0.79 to 4.95)	13 mm (8.5 to 26 mm)	99.1%	0.33 mm
Villarinho	2017	Clinical	1.6±0.3 mm		91.3%	0.3±0.5 mm
Zadeh	2017	Anatomical	Test: 1.78 (1.13 to 2.8); Control: 0.93 (0.59 to 1.39)	Test: 10.67 (6.8 to 16.8); Control: 10.19 (6.5 to 15.3)	Test: 96%; Control: 99%	Test: 0.04 mm; Control: −0.02 mm

B (C/I-R 1–1.99): 0.03 mm, group C (C/I-R >2): 0.02 mm. Di Fiore *et al.* (17) studied 108 implants retrospectively with a mean C/I-R of 2.21 mm. The mean MBL reported was 1.42 mm. Guljé *et al.* (18) analyzed 47 implants in a perspective study. The mean C/I-R was 2.14 with a MBL reported of 0.13 mm. Hadzik *et al.* (19) studied perspectively 30 implants with an anatomical ratio of 1.69. MBL reported was 0.34 mm. Hingsammer *et al.* (20) in a perspective study analysed 76 implants. The mean C/I-R was 1.70 with a MBL of 0.71 mm. Lee *et al.* (21) studied retrospectively 175 implants with a mean C/I-R of 1.06, MBL reported was 0.93 mm. Malchiodi *et al.* (22) analyzed 280 implants in a perspective study. In the study was reported both the anatomical and the clinical ratio, that was respectively 1.84 and 2.08. The MBL calculated was 0.48 mm. Mangano *et al.* (23) studied 68 implants perspectively. The mean C/I-R was 1.70. After 5 years of loading, a mean MBL of 0.38 and 0.48 was reported in the C/I <2 and C/I >2 groups, respectively. Naenni *et al.* (24) analyzed 96 implants in a perspective cohort study. The 6-mm and the 10-mm had a mean C/I-R of 1.75 and 1.04, respectively. The mean MBL calculated was 0.29 mm for the 6-mm group, and 0.15 mm for the 10-mm group. Nunes *et al.* (25) studied 118 implants retrospectively. The mean C/I-R was 2.53 and the MBL calculated was 0.67 mm. Pieri *et al.* (26) in a perspective study analyzed 61 implants with a mean C/I-R of 1.94 mm. The MBL calculated at 2 years was 0.60 mm. Ramaglia *et al.* (27) studied perspectively 78 implants with a mean C/I-R of 1.08. MBL at 5-year was calculated separately for the C/I-R <1 and C/I-R >1 group and was 0.653 and 0.287 mm respectively. Rossi *et al.* (28) in a perspective study confronted two groups of 30 implants each. The mean C/I-R for test and control group was 1.55 and 0.97 respectively. After 5-year loading MBL calculated was 0.14 mm for test group and 0.18 mm for control group. Schneider *et al.* (29) in a retrospective study analyzed 100 implants. In the study was reported both the anatomical and the clinical C/I-R of 1.04 and 1.48 respectively. The MBL calculated was 0.008 mm. Sharmann *et al.* (30) analyzed perspectively two different groups of 47 implants each. The mean C/I-R reported was 0.86 for the control group and 1.48 for the test group. The mean MBL calculated after 3 years were 0.19 and 0.33 for the test and control groups respectively. Urdaneta *et al.* (31) in a retrospective study analyzed 326 implants with a mean C/I-R of 1.6. The mean MBL found was 0.33 mm. Villarinho *et al.* (32) analyzed 46 implants perspectively. The mean C/I-R reported was 1.6 with a MBL of 0.3 mm. Zadeh *et al.* (33) analyzed perspectively

Table 2 Studies included in the review—part 2

Article	Type of study	Follow-up	N° of patients and implants	Localization	Type of prosthesis	Type of implant	Length	Diameter
Anitua *et al.*	Retrospective	23.18± 7.7 months	34 patients, 45 implants	Mandible	FDP	–	5.5, 6.5 mm	3,75, 4.0, 4.5, 5.0 mm
Birdi *et al.*	Retrospective	20.9 months (range, 15.6–122.8 months)	194 patients, 309 implants	Maxilla and mandible	Single crown	Bicon	5.7, 6.0 mm	–
Blanes *et al.*	Perspective	1 year	83 patients, 192 implants	Posterior regions mandible and maxilla	Ceramic-to-metal fused fixed partial dentures or single crown	ITI	8.01+−1.45 mm	–
Di Fiore *et al.*	Retrospective	16 years (11–20 years)	51 patients, 108 implants	Posterior mandible	39 implants (36.1%) single crown; 69 implants (63.9%) multiple FDP	–	7 mm	3.75 mm (70.4 %); 4.1 mm (29.6%)
Guljé *et al.*	Perspective	12 months	37 patients, 47 implants	Maxilla and mandible	Single crown	Astra Tech OsseoSpeed	6 mm	4 mm
Hadzik *et al.*	Perspective	36 months	30 patients, 30 implants	Maxilla	Cemented single crown	OsseoSpeed	6 mm	4 mm
Hingsammer *et al.*	Perspective	20.52 months	30 patients, 76 implants	Maxilla and mandible	Splinted crown	NobelSpeedy Groovy Shorty	6.5 mm	4 mm
Lee *et al.*	Retrospective	5.7±2.0 years	259 patients, 175 implants	Maxilla and mandible	137 single crowns, 122 splinted crowns	3 different implant systems	–	–
Malchiodi *et al.*	Perspective	3 years	151 patients, 280 implants	Maxilla and mandible	102 single crown; 157 FPDs	–	5 mm (27.0 %); 7 mm (31.3 %); 9 mm (34.0 %); 12 mm (7.7%)	4.1 mm (60.6%); 5 mm (39.4%)
Mangano *et al.*	Perspective	5 years	50 patients, 68 implants	Maxilla and mandible	49 single crowns; 9 FDP	Leone	6.5 mm	5 mm
Naenni *et al.*	Perspective	5±0.7 years	96 patients (86 after 5 years), 96 implants	Maxilla and mandible	Single crown	Standard Plus Tissue Level Implant (Straumann)	Case: 6 mm; Control: 10 mm	4.1 mm
Nunes *et al.*	Retrospective	36 months	59 patients, 118 implants	Maxilla and mandible	28 single crown; 90 splinted crowns	–	7 mm	4 mm
Pieri *et al.*	Perspective	2 years	25 patients, 61 implants	Mandible	FDP	OsseoSpeed (Astra Tech)	6 mm	4 mm

Table 2 (*continued*)

Table 2 (*continued*)

Article	Type of study	Follow-up	N° of patients and implants	Localization	Type of prosthesis	Type of implant	Length	Diameter
Ramaglia *et al.*	Perspective	5 years	78 implants	Mandible and maxilla	Metal ceramic crown	–	<10-mm long: 35 implants; ≥ 10-mm long (from 10 to 15 mm): 43 implants	–
Rossi *et al.*	Perspective	5 years	45 patients, 30 test implants, 30 control implants	Maxilla and mandible	–	Straumann AG, with a SLA modified surface	Case: 6 mm; Control: 10 mm	4.1 mm
Schneider *et al.*	Retrospective	6.2 years (4.73 to 11.7 years)	70 patients, 100 implants	Maxilla and mandible	Single crown	24 Straumann, 76 Branemark	11.5 mm (7 to 15 mm)	3.75–4.1 mm: 66%; 4.8–5 mm: 34%
Sharmann *et al.*	Perspective	36 months	47 control implants, 47 test implants	Maxilla and mandible	Single crown	Straumann	Case: 6 mm; Control: 10 mm	4.1 mm
Urdaneta *et al.*	Retrospective	70.7±23 months	81 patients, 326 implants	Maxilla and mandible	Single crown	Bicon	6 mm; 8 mm; 11 mm; 14 mm	3.5 mm; 4 mm; 4.5 mm; 5 mm; 6 mm
Villarinho *et al.*	Perspective	45±9 months	20 patients, 46 implants	Maxilla and mandible	Single Crown	Straumann Standard Plus	6 mm	4.1 mm
Zadeh *et al.*	Perspective	3 years	95 patients, 209 implants	Maxilla and mandible	FDPs	OsseoSpeed	Test 6 mm; Control 11 mm	4 mm

for 3 years 209 implants divided in two groups. The C/I-R was 1.78 for the test group and 0.93 for the control group. The analysis of MBL revealed that the test group gained 0.04 mm while the control group losed 0.02 mm. Overall, the highest follow-up reported was 16 years for the retrospective studies and 5 years for the prospective studies. The highest C/I-R reported was 2.5.

Biomechanically, unfavourable ratio may influence marginal bone through the lever mechanism. When subjected to lateral forces, implant restorations with long lever arm generate greater stress at the bone crest. It has been demonstrated in a cantilever model that crown height increased from 10 to 20 mm, lead to a proportional moment increment (34). C/I-R is calculated as the ratio between the crown and implant lengths. We can distinguish two different C/I-R:

- ❖ Anatomical ratio is the ratio between the distance from the apex to the shoulder of the implant, and the distance from the shoulder of the implant to the end of the crown;
- ❖ Clinical ratio is the ratio between the distance from the apex to the bone level, and the distance from the bone level to the end of the crown.

Clinical ratio is considered a more accurate since the implant-bone interface is less rigid than the connection at the implant shoulder, due to bone viscoelasticity (16). Among the studies included in this review, many concluded that the relationship between C/I-R and MBL is not significant. Urdaneta *et al.* (31) concluded that larger CI ratio led to an increase in prosthetic complications but had no significant influence on MBL. In this study 16% of the sample had CI ratio >2. Nunes *et al.* (25) found a weak inverse correlation between CI ratio and MBL. Blanes *et al.* (16) stated that there were no statistical relationship between CI ratio and MBL. Birdi *et al.* (15) found no significant relationship between CI ratio and first bone-to-implant contact levels. Schneider *et al.* (29) concluded that technical and biological CI ratio had no significant correlation on the MBL, technical and biological complications and implant survival. Mangano *et al.* (23) found no correlation between MBL and CI ratio along time, with a 0.023 mm increase in 1-year bone resorption for every 0.1 increase in CI ratio. However, other studies found a stronger correlation between C/I-R and MBL. Di Fiore *et al.* (17) showed that, at multivariable analysis, C/I-R >2 was correlated with higher MBL. It was estimated that C/I-R >2 led to an increase of 0.28 mm in MBL. However, the authors underlined that this increment could be considered clinically irrelevant. Hingsammer *et al.* (20) concluded that a MBL of 0.71 mm is considered to be satisfactory and a C/I-R of 1.7 can be considered as a threshold to avoid early marginal bone changes. Malchiodi *et al.* (22) showed that implants with C/I ratio >2 had a MBL of 0.72 mm. Statistical analysis revealed that both anatomical and clinical CI ratio had a correlation with MBL. The authors concluded that, from a biomechanical point of view, to avoid excessive bone loss, anatomical and clinical C/I ratio should not exceed respectively 3.1 and 3.4. It was seen that C/I ratio resulted the main factor correlated to implant success and crestal bone loss.

The difference between all this findings can be found in various aspects. Many studies mixed together implants of different lengths; moreover, the definition of short implant is not standardized. Tawil and Younan considered short an implant <10 mm (35). Nisand and Renouard defined "short" implants with a length of <8 mm and extra-short the one <5 mm (36). Since the length of the implant seems not to be correlated to the lever mechanism, the portion that may be significantly correlated is the crown. In many of the previous mentioned studies, the crown-height-space was not considered in relation to CI ratio. Anitua *et al.* (14) analysed 45 extra-short implants with a mean CI ratio of 2.4 and a mean CHS of 17.05. Results showed that implants with MBL <2 mm had a mean CHS of 17 mm, while implants with MBL >2 had a mean CHS of 21 mm. Statistical analyses revealed that CHS had a positive correlation with bone loss. Nissan *et al.* (37) in an *in vitro* study showed that an increased crown height from 6 to 12 mm, in case of off-axis loading of 30 degrees determined a proportional increase stress distribution (17.72 *vs.* 30.09 MPa). CHS higher than 15 mm is considered as biomechanically unfavourable, resulting in increased stress at bone level. Failure were noted at CHS >15 mm and CI ratio at 1.75 when force application was at 30 degrees. The authors concluded that CHS is more significant than CI ratio in the evaluation of the adverse effects related to biomechanics, and studies about the effects of C/I ratio should mention both implant length and CHS in their results.

In this review was considered both splinted and unsplinted implants. Many studies underline that splinting crowns together could better distribute non-axial forces, minimizing their load to the restoration and bone, and increasing the load area (7). Moreover, splinting is recommended in case of poor quality bone to be reduced the marginal bone stress under horizontal load (38). Therefore, splint implants could alter the real impact of C/I-R on MBL resulting in less cervical stress for a better forces distribution. However, in an *in vitro* study Nissan *et al.* (37) proved the splinting implants can result in greater crestal bone loss.

In conclusion, according to a recent consensus of EAO (39), is possible to state that crown-to-implant not exceed 2.2 did not influence the possibility of biological complications and lead to a not significant MBL. Further research should investigate the complications of higher ratios, the implications of splinted implants on forces distribution and the role of crown height on MBL.

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Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at http://dx.doi.org/10.21037/fomm-20-57

Conflicts of Interest: All the authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/fomm-20-57). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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