

SYSTEMATIC REVIEW

# Finish-line designs for ceramic crowns: A systematic review and meta-analysis



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Ceramic crowns have been widely applied in dentistry because of their excellent esthetic properties and biocompatibility.<sup>1</sup> A recently published systematic review confirmed that ceramic crowns demonstrate acceptable survival rates compared with conventional metal-ceramic crowns.<sup>2</sup> The adaptation of restorations, including marginal and internal adaptations, is important for clinical success.<sup>3,4</sup> Poor marginal or internal adaptation can result in cement dissolution, microleakage, and increased plaque retention, potentially leading to caries and periodontal disease.<sup>3,5-7</sup> In addition, the fracture strength of restorations can be influenced by poor marginal and/or internal adaptations due to higher stress concentrations at the margins and/or internal surfaces.<sup>8,9</sup>

Marginal adaptation is generally determined by measuring the perpendicular distance between the prepared tooth and the internal surface of the restoration at the margin (marginal gap) or an angular combination of a marginal gap and extension error (absolute marginal discrepancy).<sup>10</sup> Although the American Dental Association

## ABSTRACT

**Statement of problem.** Different finish-line designs have been advocated for tooth preparations of ceramic crowns. However, scientific evidence is lacking to help clinicians make a proper selection.

**Purpose.** The purpose of this systematic review and meta-analysis was to evaluate the effects of finish-line designs on the marginal and internal adaptations of ceramic crowns.

**Material and methods.** This report follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The literature search was conducted in MEDLINE via the PubMed, Embase, and Web of Science databases with no publication year or language limits. In vitro studies comparing the marginal and internal adaptations of ceramic crowns with rounded shoulder and chamfer finish lines were included in the meta-analysis.

**Results.** Sixteen studies were included in the qualitative synthesis and meta-analyses. Statistical analyses were conducted using the Review Manager Software. Meta-analyses were performed with random-effects models ( $\alpha=.05$ ). Ceramic crowns with rounded shoulders exhibited significantly better marginal adaptation than those with chamfers ( $P<.001$ ; mean difference=-7.8; 95% confidence interval=-11.6 to -4.1). Moreover, ceramic crowns with chamfers exhibited significantly better internal adaptation than those with rounded shoulders ( $P=.020$ ; mean difference=35.0; 95% confidence interval=6.5 to 63.5).

**Conclusions.** The difference in marginal adaptation of ceramic crowns using 2 finish-line designs was small, and the clinical significance was low, whereas the results of internal adaptation favored the chamfer finish line. (J Prosthet Dent 2019;122:22-30)

states that film thickness should not exceed 25  $\mu\text{m}$  for Type I cement and 40  $\mu\text{m}$  for Type II cement, this level of marginal adaptation has seldom been reached clinically.<sup>3,11</sup> The most accepted limit for clinically acceptable marginal adaptation was proposed by McLean and von Fraunhofer.<sup>12</sup> After the examination of more than 1000 fixed restorations over a 5-year period, these authors concluded that 120  $\mu\text{m}$  was the maximum tolerable marginal opening.

This study was supported in part by the Fund for Youth Talents, Fujian Province (grant no.: 2014); the Fund for Youth Talents, School and Hospital of Stomatology, Fujian Medical University (grant no.: KQYY-BJ-1); and the Fund for Direction Program Fujian Province (grant no.: 2018Y0029).

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## Clinical Implications

The choice of a chamfer finish line in clinical practice appears to be better for ceramic crowns as restorations with chamfer finish lines exhibited better internal adaptation and comparable marginal adaptation than those with rounded shoulder finish lines.

Internal adaptation is defined as the perpendicular distance from the internal surface of the restoration to the axial wall of the preparation.<sup>10</sup> Conclusive evidence is lacking concerning clinically acceptable internal adaptation. A gap of 50 to 100  $\mu\text{m}$  is considered acceptable with respect to the physical and clinical properties of luting cements,<sup>13,14</sup> whereas studies have reported clinically acceptable restorations with internal gaps between 200 and 300  $\mu\text{m}$ .<sup>15-17</sup>

Four factors influencing marginal adaptation were identified in a previous systematic review: the finish-line configuration, value of the cementing space, veneering process, and occurrence of cementation.<sup>3</sup> Dentists have full control of the finish line of the preparation, whereas the remaining factors are less predictable. The influence of finish lines on the marginal and/or internal adaptations of ceramic crowns has been widely investigated.<sup>18-22</sup> Rounded shoulders and chamfers have been advocated by the manufacturers of various ceramic systems. Borelli et al<sup>23</sup> compared the residual tooth structure of teeth with various finish lines and concluded that shoulder was the most invasive finish line and that chamfer and knife edge were more conservative and comparable. For minimally invasive dentistry, more conservative preparation geometries, such as chamfer, might be a better choice than a rounded shoulder. However, which finish line offers better marginal and internal adaptations is not clear. A recently published systematic review concluded that the majority of the few available studies indicated that the marginal adaptation was optimal for a chamfer finish line.<sup>24</sup> However, the results of another systematic review were somewhat conflicting.<sup>3</sup>

Although tooth preparation is part of the daily routine, dentists select the cervical finish line based mainly on their experience and personal choice.<sup>25</sup> Systematic reviews and meta-analyses are needed to provide evidence-based recommendations. Therefore, the purpose of this systematic review and meta-analysis was to evaluate the influences of rounded shoulder and chamfer on the marginal and internal adaptations of ceramic crowns. The null hypothesis tested was that no difference would be found in the marginal and internal adaptations of ceramic crowns using rounded shoulder or chamfer finish lines.

## MATERIAL AND METHODS

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.<sup>26</sup> A systematic electronic literature search was conducted in MEDLINE via PubMed, EMBASE, and the Web of Science databases. In addition, manual searches were conducted in these principal periodicals specific to the area of study: *Journal of Prosthetic Dentistry*, *Journal of Dental Research*, *Journal of Dentistry*, *Operative Dentistry*, *Clinical Oral Investigations*, *Journal of Oral Rehabilitation*, *International Journal of Prosthodontics*, *Journal of Prosthodontic Research*, *Dental Materials Journal*, *Journal of Prosthodontics*, and *Zhonghua Kou Qiang Yi Xue Za Zhi* (a journal published in Chinese). The search included peer-reviewed publications, with no publication year or language limits. The last search was executed on June 23, 2018.

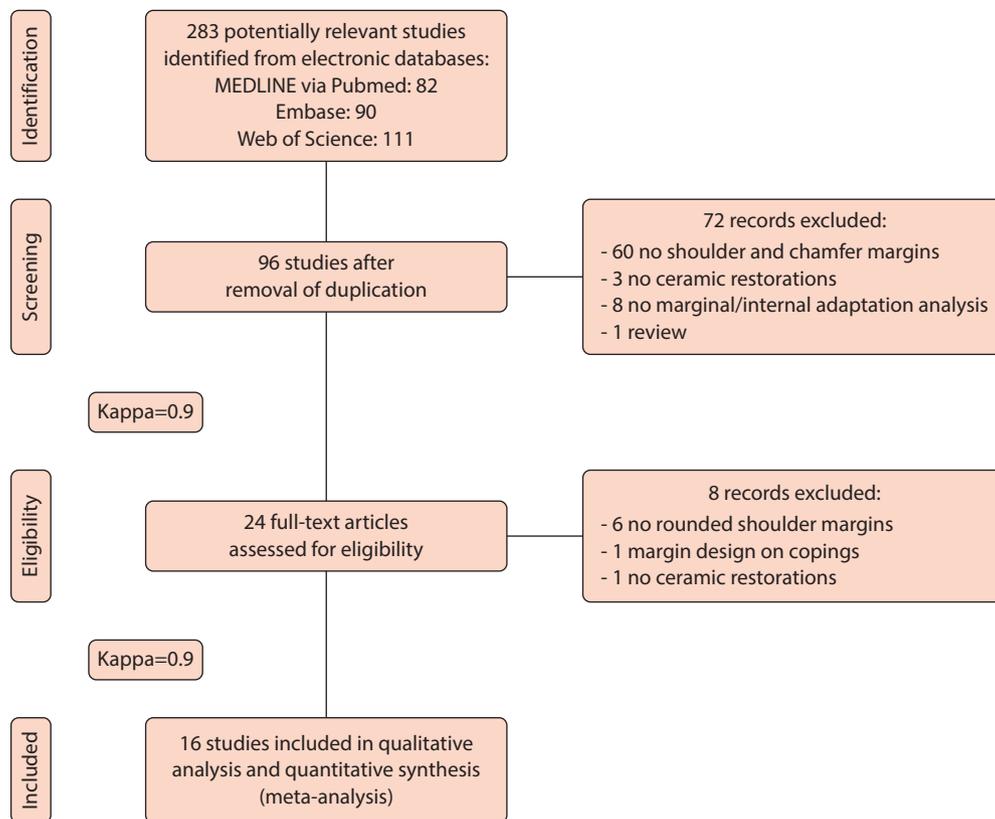
The following MeSH terms, search terms, and their combinations were used in the PubMed search: (((“all ceramic” OR “glass ceramic” OR “zirconium oxide” [MeSH Terms] OR “yttria-stabilized tetragonal zirconia polycrystal” [MeSH Terms] OR “aluminum oxide” [MeSH Terms]))) AND (“finish line” OR margin OR shoulder OR chamfer) AND (“marginal gap” OR “marginal discrepancy” OR “marginal fit” OR “marginal adaptation” OR “internal fit” OR “internal adaptation”).

The following terms were used in the Embase search: (‘all ceramic’ OR ‘glass ceramic’ OR ‘zirconium oxide’ OR ‘yttria-stabilized tetragonal zirconia polycrystal’ OR ‘aluminum oxide’) AND (‘finish line’ OR margin OR shoulder OR chamfer) AND (‘marginal gap’ OR ‘marginal discrepancy’ OR ‘marginal fit’ OR ‘marginal adaptation’ OR ‘internal fit’ OR ‘internal adaptation’).

The following terms were used in the Web of Science search: (((“all ceramic” OR “glass ceramic” OR “zirconium oxide” OR “yttria-stabilized tetragonal zirconia polycrystal” OR “aluminum oxide”))) AND (“finish line” OR margin OR shoulder OR chamfer) AND (“marginal gap” OR “marginal discrepancy” OR “marginal fit” OR “marginal adaptation” OR “internal fit” OR “internal adaptation”).

Articles that met the following inclusion criteria were included in this systematic review: studies that evaluated the marginal and/or internal adaptations of ceramic crowns; studies that evaluated restorations with rounded shoulder and chamfer finish lines; and studies including well-described marginal and/or internal adaptation measurements. The authors of the studies were contacted in cases of unpublished data. These studies were only included if the authors provided the missing information.

Articles meeting one or more of the following criteria were excluded: study material other than ceramic materials; reviews, protocols, clinical guidelines,



**Figure 1.** Flow diagram of study selection according to PRISMA statement. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

or editorial letters; and studies that evaluated ceramic crowns fabricated with less popular or outdated systems. For ceramic restorations, a rounded internal geometry is considered essential to avoid tensile stress.<sup>24</sup> Therefore, studies performed to compare shoulder with chamfer finish lines were excluded from this systematic review.

After the identification of articles in the databases, the articles were imported into a software program (EndNote X8; Thomson Reuters) to remove duplicates. Two reviewers (H.Y., Y.C.) independently conducted electronic literature searches and performed study selection. Inter-examiner agreement was calculated ( $\kappa=0.9$ ), indicating excellent agreement. Any disagreements were resolved by discussion or by consulting another reviewer (T.S.). The following data were extracted from the included studies: demographic information, the ceramic material tested, the stage of restoration, the means and standard deviations of internal/marginal discrepancies, sample size, type of finish line, occurrence of cementation, and evaluation method.

The risk-of-bias assessment was based on a protocol adapted from previous systematic reviews.<sup>27-29</sup> In this assessment, the description of the following parameters used for the quality assessment was evaluated: sample

size calculation, tooth preparation by a single operator, outcome evaluated after a well-accepted measurement, sintering of ceramic materials following the manufacturers' instructions, tests executed by a single blinded operator, and adequate statistical analysis. If the authors reported a parameter, the article received a "Y" for that specific parameter; if it was not possible to find this information, the article received an "N". Articles that included 1 or 2 "Y" items were classified as having a high risk of bias, those that included 3 or 4 "Y" items as a medium risk of bias, and those that included 5 to 6 "Y" items as a low risk of bias.

All the analyses were conducted using a software program (Review Manager v. 5.3; Cochrane Collaboration) using a random-effects model ( $\alpha=.05$ ). For studies that evaluated more than 1 type of ceramic material, each material was considered independently. The mean difference (MD) and 95% confidence interval (CI) were calculated. The statistical heterogeneity of the treatment effect among studies was assessed via the Cochrane Q test, in which values greater than 50% were considered indicative of high heterogeneity. Subgroup analyses were performed to identify any potential causes of heterogeneity. The subgroup analyses included the following: the ceramic systems, occurrence of cementation, and stage of restoration.

**Table 1.** Characteristics of included studies

Author/ Publication Year	Material Tested	Sample Size	State	Finish Line	Total Occlusal Convergence (°)	Cementation	Examination Method	Marginal/Internal Adaptation
Koç et al 2016 <sup>30</sup>	Zirkonzahn, Cercon, In-Ceram Alumina, e.max Press	10	Coping	Chamfer, rounded shoulder	n.a.	Yes, no	Stereomicroscope	Marginal gap
Ribeiro et al 2015 <sup>16</sup>	Zirkonzahn	10	Coping	Chamfer, tilted chamfer, rounded shoulder	6	No	3D optical microscope	Absolute marginal discrepancy, internal adaptation
Vojdani et al 2015 <sup>31</sup>	In-Ceram YZ-14	10	Coping, crown	Chamfer, rounded shoulder	6	No	Digital microscope	Marginal gap
Euán et al 2014 <sup>32</sup>	Lava	10	Coping	Chamfer, rounded shoulder	6	No	Stereomicroscope	Marginal gap
Re et al 2014 <sup>33</sup>	Lava	10	Coping	Chamfer, rounded shoulder	n.a.	No	Optical microscope	Vertical marginal discrepancy
Cho et al 2012 <sup>34</sup>	e.max Press, Empress Esthetic	20	Crown	Chamfer, rounded shoulder	10	No	Light microscope	Absolute marginal discrepancy
Subasi et al 2012 <sup>35</sup>	e.max Press, Zirkonzahn	10	Coping	Chamfer, rounded shoulder	4	Yes	Stereomicroscope	Absolute marginal discrepancy
Euán et al 2012 <sup>36</sup>	Lava	10	Coping, crown	Chamfer, rounded shoulder	6	Yes	Stereomicroscope	Absolute marginal discrepancy
Souza et al 2012 <sup>17</sup>	Empress CAD	10	Crown	Chamfer, tilted chamfer, rounded shoulder	6	No	3D optical microscope	Vertical marginal discrepancy, internal adaptation
Baig et al 2010 <sup>37</sup>	Cercon, Empress II	10	Crown	Chamfer, rounded shoulder	20	No	Stereomicroscope	Marginal gap
Comlekoglu et al 2009 <sup>38</sup>	Zirkonzahn	7	Crown	Chamfer, tilted chamfer, rounded shoulder, featheredge	6	Yes	Stereomicroscope	Absolute marginal discrepancy, marginal gap
Komine et al 2007 <sup>13</sup>	Cercon	8	Coping, crown	Chamfer, shoulder, rounded shoulder	6	Yes	Laser microscope	Marginal gap, internal adaptation
Quintas et al 2004 <sup>20</sup>	Empress 2, In-Ceram Alumina, Procera	10	Coping	Chamfer, rounded shoulder	6	Yes, no	Profile projector	Vertical marginal discrepancy
Suárez et al 2003 <sup>19</sup>	Procera	10	Coping	Chamfer, rounded shoulder	10	Yes	Magnification loupe	Absolute marginal discrepancy, marginal gap, horizontal marginal discrepancy, vertical marginal discrepancy, absolute marginal discrepancy, internal adaptation
Zhao et al 2003 <sup>21</sup>	MC Machinable feldspathic ceramic	5	Coping	Chamfer, rounded shoulder	10, 20	Yes	Stereomicroscope	Marginal gap, internal adaptation
Lin et al 1998 <sup>39</sup>	Procera	10	Coping	Chamfer, 0.5-mm rounded shoulder, 0.8-mm rounded shoulder, featheredge	10	Yes	Measuring microscope	Absolute marginal discrepancy, marginal gap, internal adaptation

## RESULTS

Among 283 potentially relevant studies, 24 were selected for full-text analysis and 16 were included in the systematic review and the meta-analysis (Fig. 1). All 16 studies were considered in the meta-analysis of marginal adaptation, whereas 4 were considered in the analysis of internal adaptation.

The characteristics of the included studies are presented in Table 1. The included articles were published between 1998 and 2016. Fifteen of the articles were in English, and 1 was in Chinese. All the 16 eligible studies were *in vitro* studies investigating ceramic crowns.<sup>13,16,17,19–21,30–39</sup> An overall review of the data retrieved for marginal adaptation showed that 95.1% of the values measured were less than 120  $\mu\text{m}$ . The

minimum number of specimens per group was 5,<sup>21</sup> and the maximum number of specimen per group was 20.<sup>34</sup> Four measurement methods were used to investigate the marginal adaptation of ceramic restorations with different finish lines, among which the direct-view technique was most commonly used (12 studies), followed by the cross-sectioning method (3 studies)<sup>19,21,38</sup> and the profile projector (1 study).<sup>20</sup> For internal adaptation, 2 studies measured the internal gap of restorations with cementation using the cross-sectioning method,<sup>19,21</sup> whereas 2 measured restorations without cementation using the replica technique.<sup>13,17</sup>

Regarding the risk-of-bias assessments, none of the included studies fulfilled all requisites (Table 2). Of the 16 studies included in this systematic review, 2 presented a

**Table 2.** Risk of bias in included studies

Author/Publication Year	Sample Size Calculation	Single Operator	Measurement	Ceramic Sintering	Blinded Examiner	Statistical Analysis	Risk of Bias
Koç et al 2016 <sup>30</sup>	Y	Y	Y	N	N	Y	Medium
Ribeiro et al 2015 <sup>16</sup>	N	Y	Y	Y	N	N	Medium
Vojdani et al 2015 <sup>31</sup>	N	N	Y	Y	N	Y	Medium
Euán et al 2014 <sup>32</sup>	Y	Y	Y	Y	N	Y	Low
Re et al 2014 <sup>33</sup>	N	N	Y	Y	N	Y	Medium
Cho et al 2012 <sup>34</sup>	N	N	Y	Y	N	Y	Medium
Subasi et al 2012 <sup>35</sup>	N	N	Y	Y	N	Y	Medium
Euán et al 2012 <sup>36</sup>	N	Y	Y	Y	N	Y	Medium
Souza et al 2012 <sup>17</sup>	N	Y	Y	Y	N	Y	Medium
Baig et al 2010 <sup>37</sup>	N	Y	Y	Y	N	Y	Medium
Comlekoglu et al 2009 <sup>38</sup>	Y	Y	Y	Y	N	Y	Low
Komine et al 2007 <sup>13</sup>	N	N	Y	Y	N	Y	Medium
Quintas et al 2004 <sup>20</sup>	N	Y	Y	N	N	Y	Medium
Suárez et al 2003 <sup>19</sup>	N	N	N	Y	N	Y	High
Zhao et al 2003 <sup>21</sup>	N	N	Y	N	N	Y	High
Lin et al 1998 <sup>39</sup>	N	N	Y	Y	Y	Y	Medium

low risk of bias, 2 presented a high risk of bias, and the majority (12 studies) showed a medium risk of bias.

In the general meta-analysis of marginal adaptation in eligible studies (Fig. 2), the results showed a significant difference in marginal adaptation between the restorations with rounded shoulder and those with chamfer finish lines ( $P < .001$ ; MD = -7.8; 95% CI = -11.6 to -4.1), favoring rounded shoulder. The chi square of heterogeneity was 311.65 ( $P < .001$ ;  $I^2 = 80\%$ ).

In the general meta-analysis of internal adaptation based on eligible studies (Fig. 3), the results showed a significant difference in internal adaptation between the crowns with rounded shoulder and those with chamfer finish lines ( $P = .020$ ; MD = 35.0; 95% CI = 6.5 to 63.5), favoring chamfer. The chi square of heterogeneity was 138.80 ( $P < .001$ ;  $I^2 = 89\%$ ).

The possible sources of heterogeneity were assessed through subgroup analyses of marginal and internal adaptations (Tables 3 and 4). As seen in Supplementary Figures 1 to 6, subgroup analyses revealed that the stage of restoration may contribute to the marginal adaptation of the restorations with different finish lines ( $P = .060$ ).

## DISCUSSION

Tooth preparation is the first step in the workflow, leading to a successful restoration, which requires proper selection of cervical finish lines.<sup>3,40</sup> Different finish-line designs have been advocated for tooth preparations of ceramic crowns.<sup>3,24,40</sup> Moreover, the studies evaluating the effect of finish-line design on the marginal and internal adaptations of ceramic crowns have produced diverse and sometimes conflicting results.<sup>16,17,30,31,33-36</sup> This review assessed the effect of the finish lines on the

internal and marginal adaptations of ceramic crowns. The authors are unaware of a previous systematic review and meta-analysis in this field. Based on the existing data, the null hypothesis of no difference between the marginal and internal adaptations of ceramic crowns using rounded shoulder versus chamfer finish lines was rejected.

A minor but statistically significant difference in marginal adaptation was detected in the meta-analysis, favoring the rounded shoulder. It is possible that the tilted surfaces of a chamfer finish line complicate the production of restorations.<sup>41</sup> Compared with a rounded shoulder finish line, more fractures were observed at the margins of crowns with chamfer finish lines.<sup>17</sup> During coping design, the margin of restoration is usually thickened to prevent defects at the margin during milling.<sup>42</sup> This reinforcement is then manually removed during the adjustment process in the dental laboratory. The procedure may be more complicated to perform when there is a chamfer finish line.<sup>36</sup> However, because the MD in marginal adaptation was only 7.9  $\mu\text{m}$ , this finding may have only limited clinical relevance. It can be assumed that both rounded shoulder and chamfer finish lines provide adequate marginal adaptation of ceramic crowns.

Although an internal gap of 50 to 100  $\mu\text{m}$  is considered acceptable with respect to the physical and clinical properties of luting cements,<sup>13,14</sup> this level of internal adaptation has seldom been reached.<sup>16,17,19,21</sup> Assuming that an internal gap between 200 and 300  $\mu\text{m}$  is clinically acceptable,<sup>15-17</sup> both rounded shoulder and chamfer finish lines were found to be appropriate for ceramic crowns. A significant difference in internal adaptation was found between the crowns with rounded shoulder and those with chamfer finish lines: 35.0  $\mu\text{m}$  ( $P = .020$ ;

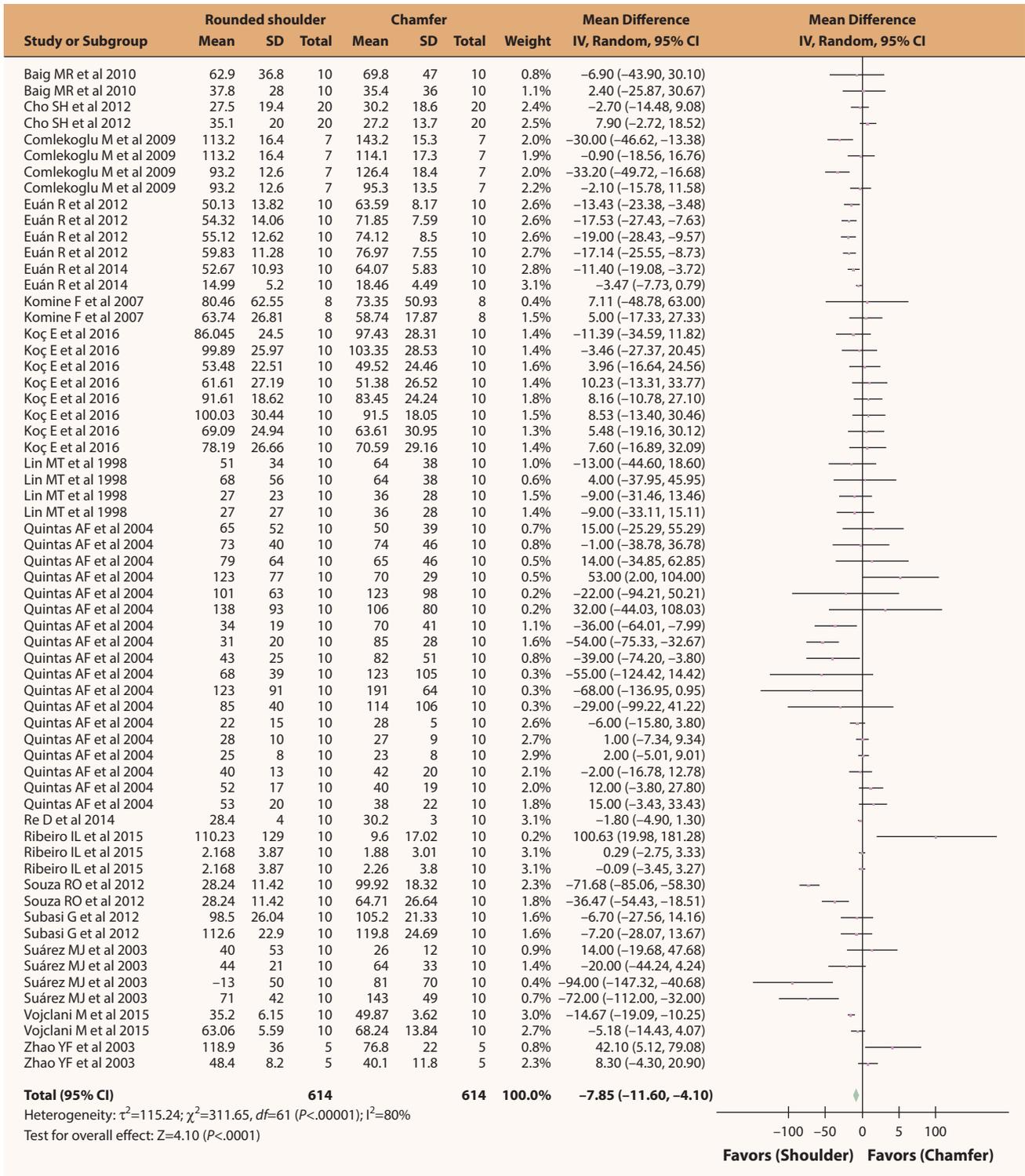


Figure 2. Forest plot summarizing marginal adaptation of ceramic crowns. CI, confidence interval; SD, standard deviation.

95% CI=6.5 to 63.5). The relatively better seating (smaller internal gap) of restorations with chamfer preparation appeared to correlate with their poor marginal sealing (greater marginal gap). A smaller internal space may lead to premature contact between the internal surface of the

restoration and preparation and hinder the cement evacuation, thus widening the marginal gap.<sup>43</sup> Theoretically, during the cementation process, the escape path for the cement decreases, causing hydrostatic pressure within the restoration to increase until it matches the

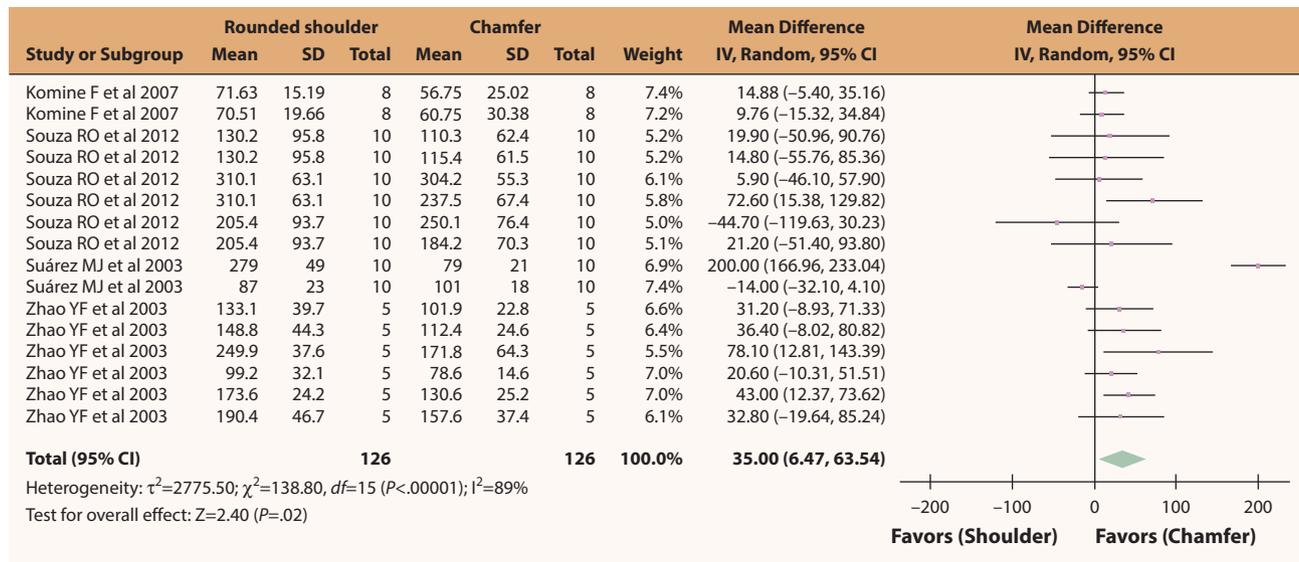


Figure 3. Forest plot summarizing internal adaptation of ceramic crowns. CI, confidence interval; SD, standard deviation.

Table 3. Subgroup meta-analysis of marginal adaptation of ceramic crowns (rounded shoulder versus chamfer)

Category	Studies (n)*	MD (95% CI)	P	Test of Subgroup Heterogeneity
Ceramic system				
Conventional ceramic system	20	-5.72 (-16.20 to 4.77)	.29	$P=.62$
CAD-CAM system	42	-8.58 (-12.70 to -4.47)	<.001	
Occurrence of cementation				
With cementation	32	-5.47 (-12.68 to 1.73)	.14	$P=.37$
Without cementation	30	-9.41 (-13.97 to -4.84)	<.001	
Stage of restoration				
Crown	11	-15.38 (-25.34 to -5.42)	.002	$P=.06$
Coping	51	-4.92 (-8.82 to -1.14)	.01	

CAD-CAM, computer-assisted design and computer-assisted manufacturing; CI, confidence interval; MD, mean difference. \*Each of test groups considered separate study.

Table 4. Subgroup meta-analysis of internal adaptation of ceramic crowns (rounded shoulder versus chamfer)

Category	Studies (n)*	MD (95% CI)	P	Test of Subgroup Heterogeneity
Ceramic system				
Conventional ceramic system	2	92.54 (-117.18 to 302.25)	.39	$P=.52$
CAD-CAM system	14	23.21 (12.66 to 33.76)	<.001	
Occurrence of cementation				
With cementation	8	53.08 (1.52 to 104.63)	.04	$P=.16$
Without cementation	8	14.47 (0.94 to 27.99)	.04	
Stage of restoration				
Crown	7	14.75 (-5.69 to 35.19)	.16	$P=.16$
Coping	9	48.40 (6.17 to 90.64)	.02	

CAD-CAM, computer-assisted design and computer-assisted manufacturing; CI, confidence interval; MD, mean difference. \*Each of test groups considered separate study.

seating force. At this point, the crown fails to seat further. Until the cement sets, it will continue to escape until the cement at the axial walls prevents further seating of the restoration.<sup>44</sup> It is possible that the design of chamfer allows the cement to escape marginally more readily without filtration, whereas with the rounded shoulder, the margins seal earlier and the filtration of the cement begins sooner.<sup>20</sup> Notably, the effect of finish-line designs on marginal and internal adaptations of partial coverage restorations would be different because the cement escape might be better with a partial coverage restoration. Overall, combined with the evidence that a chamfer finish line requires less invasive tooth preparation,<sup>23</sup> the present findings indicated that a chamfer rather than a rounded shoulder is preferable for ceramic crowns.

Based on the subgroup analyses, the differences in marginal adaptation between the restorations with the 2

finish lines were found to be related to the stage of restoration (crown and coping). Increased marginal gaps due to the veneering process were confirmed by all 3 included studies;<sup>13,31,36</sup> however, not all the differences were significant. Firing of the ceramic restoration occurs at temperatures above the glass transition temperature and up to the sintering temperature of the veneering material. Once achieved, the temperature decreases at a high rate, resulting in considerable stresses, which can lead to significant distortion of the marginal area.<sup>45</sup> The shoulder preparation may be more resistant to this type of distortion.<sup>46</sup> In addition, the contamination of the internal surface from veneering porcelain firing near the margins could result in incomplete seating of the restoration, adding to the overall marginal gap. Moreover, the other 2 factors, whether the crowns were fabricated by conventional or computer-assisted design and

computer-assisted manufacturing (CAD-CAM) systems and whether the crowns were cemented, were found to be unrelated to the differences in marginal and internal adaptations between the ceramic crowns with the 2 finish lines based on the subgroup analyses.

The risk of bias was found to be medium in 12 of the studies included in the present review, which, together with the high heterogeneity, highlights the need for standardized methods in future investigations. Notably, there was a considerable variation in the marginal gap measurements (4 to 50 per crown). Groten et al<sup>47</sup> reported that the measurement of crown margins at 4 to 12 sites per crown margin might be misleading, especially when the adaptation of various ceramic systems or stages of restoration is compared. Moreover, the results from limited measuring points should be compensated by a large specimen number per group.<sup>22</sup> However, in most of the included studies, these numbers fell within the range of 7 to 10 specimens per group, and the calculated means usually exhibited large standard deviations. Furthermore, some studies included internal surface adjustments before measurements,<sup>17,35,38</sup> which may also contribute to the high heterogeneity shown in the meta-analyses.

The present study did not consider the effect of cement space because the values of cement spaces varied widely, which can be considered as a limitation of the study. The present findings should be interpreted with caution before being applied to clinical situations because all included studies were in vitro studies. Long-term clinical data are needed before clinical recommendations can be made.

## CONCLUSIONS

Within the limitation of this systematic review and meta-analysis, the following conclusions were drawn:

1. Ceramic crowns with chamfer finish lines showed wider marginal gaps than those with rounded shoulder finish lines (MD=-7.8; 95% CI=-11.6 to -4.1).
2. Ceramic crowns with rounded shoulder finish lines showed wider internal gaps than those with chamfer finish lines (MD=35.0; 95% CI=6.5 to 63.5).

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**Acknowledgments**

The authors thank Dr Zhi-jian Hu, Biostatistics Department, Fujian Medical University, for his help with the statistical analysis.

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<https://doi.org/10.1016/j.prosdent.2018.10.002>

## Noteworthy Abstracts of the Current Literature

### Patient-specific, risk-based prevention, maintenance, and supportive care: A need for action and innovation in education

Afshari FS, Campbell SD, Curtis DA, Garcia LT, Knoernschild KL, Yuan JC

*J Prosthodont* 2019 Mar 29 [Epub ahead of print]

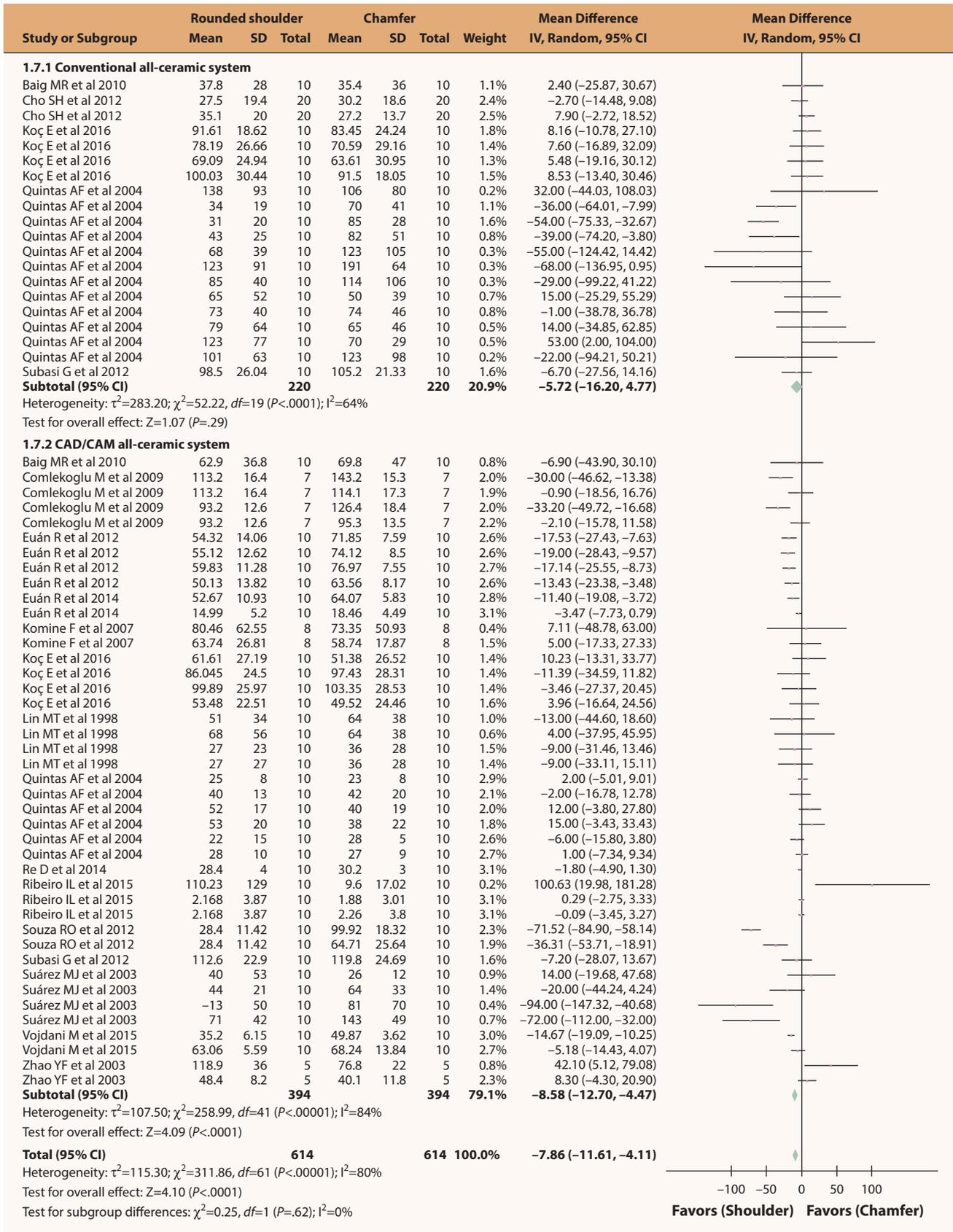
**Purpose.** To develop a competency-based curriculum framework for prevention, supportive care, and maintenance for use in educational and patient care programs and to seek consensus on an overarching competency statement that embraces these critical learning and patient care concepts.

**Material and methods.** A preliminary survey of current preventive and maintenance practices in U.S. dental and prosthodontic programs was completed and summarized with quantitative analysis. The American College of Prosthodontists organized a one-day consensus workshop with 14 participants from various U.S. dental schools with diverse backgrounds to develop a curriculum framework. The curriculum framework was used in the development of a joint competency statement using an iterative, online consensus process of debate and feedback.

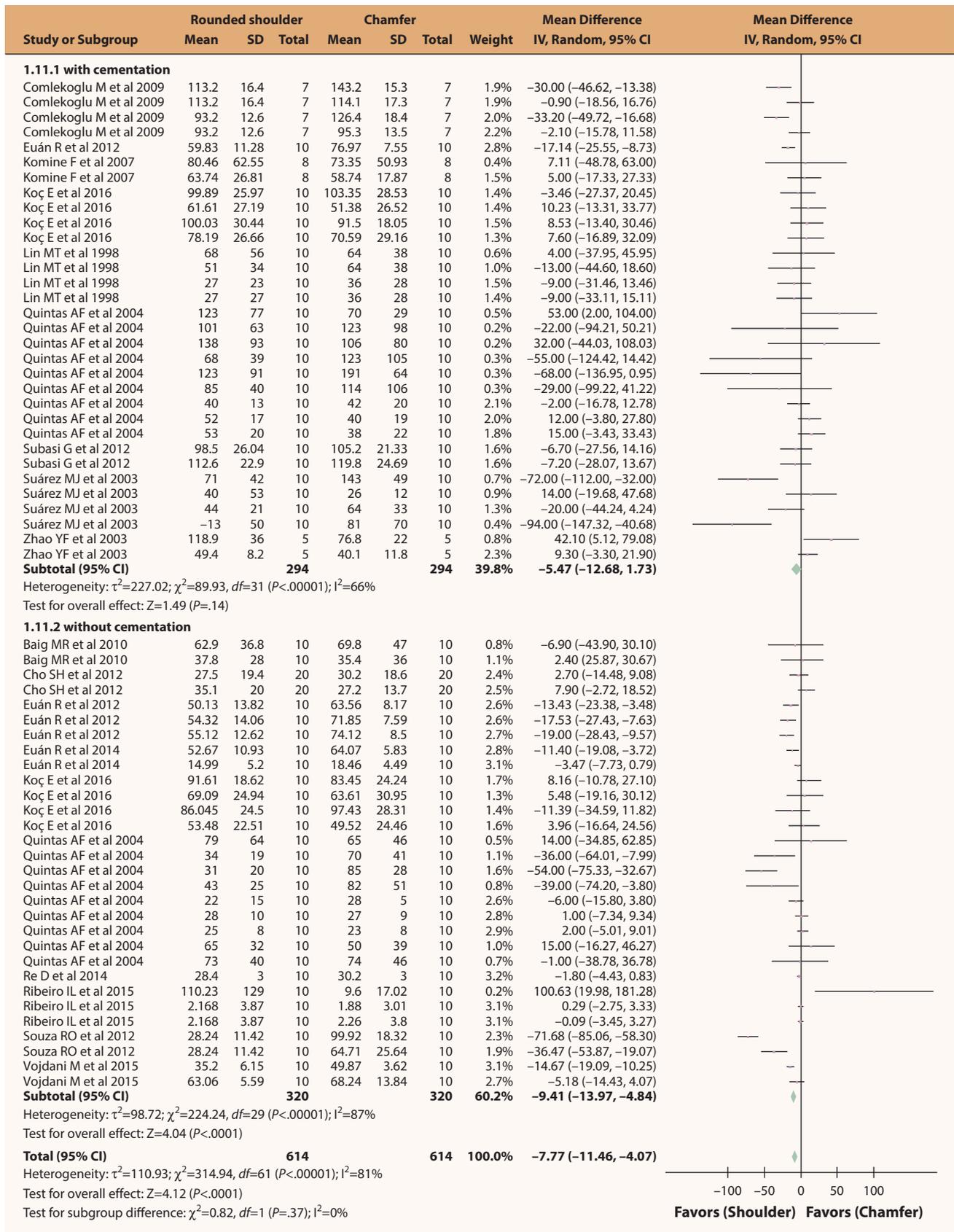
**Results.** The preliminary survey helped frame the initiative and identify potential educational needs and gaps. Consensus was achieved for a recommended competency statement: "Graduates must be competent in promoting oral health through risk assessment, diagnosis, prevention, and management of the hard tissue, soft tissue, and prostheses, and as part of professional recall and home maintenance." This competency statement complements the proposed curriculum framework designed around 3 domains-caries prevention, periodontal supportive care, and prosthesis supportive care-with a set of recommended learning objectives.

**Conclusions.** Commission on Dental Accreditation (CODA) learning standards do not outline patient-customized, evidence-based recall and home maintenance programs that highlight prevention of dental caries, periodontal supportive care, prosthesis maintenance, and patient education. The proposed competency-based curricular framework serves as an initial step in addressing student learning and patient care within the context of a recall system and home maintenance program while offering schools the needed flexibility for implementation within their curriculum.

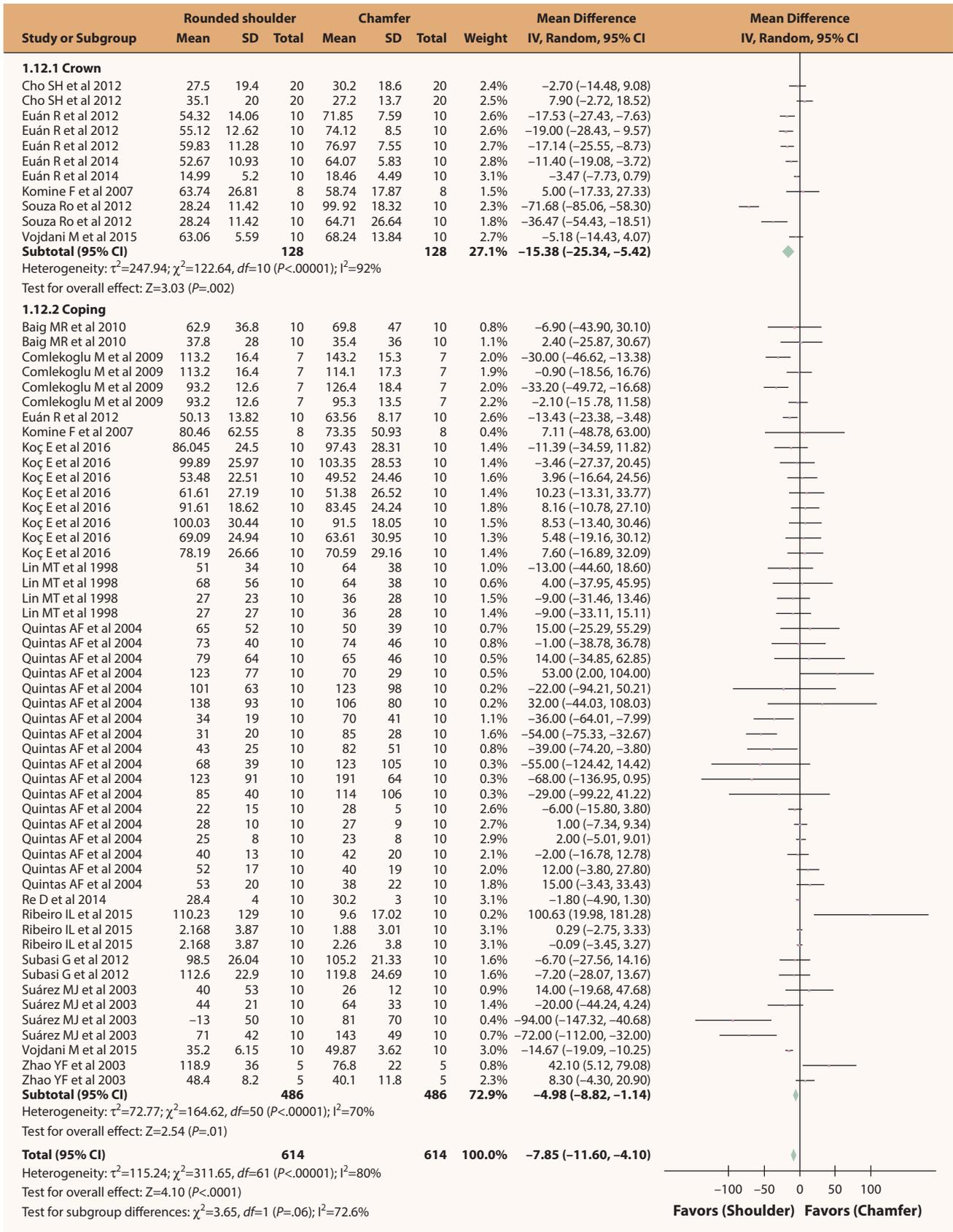
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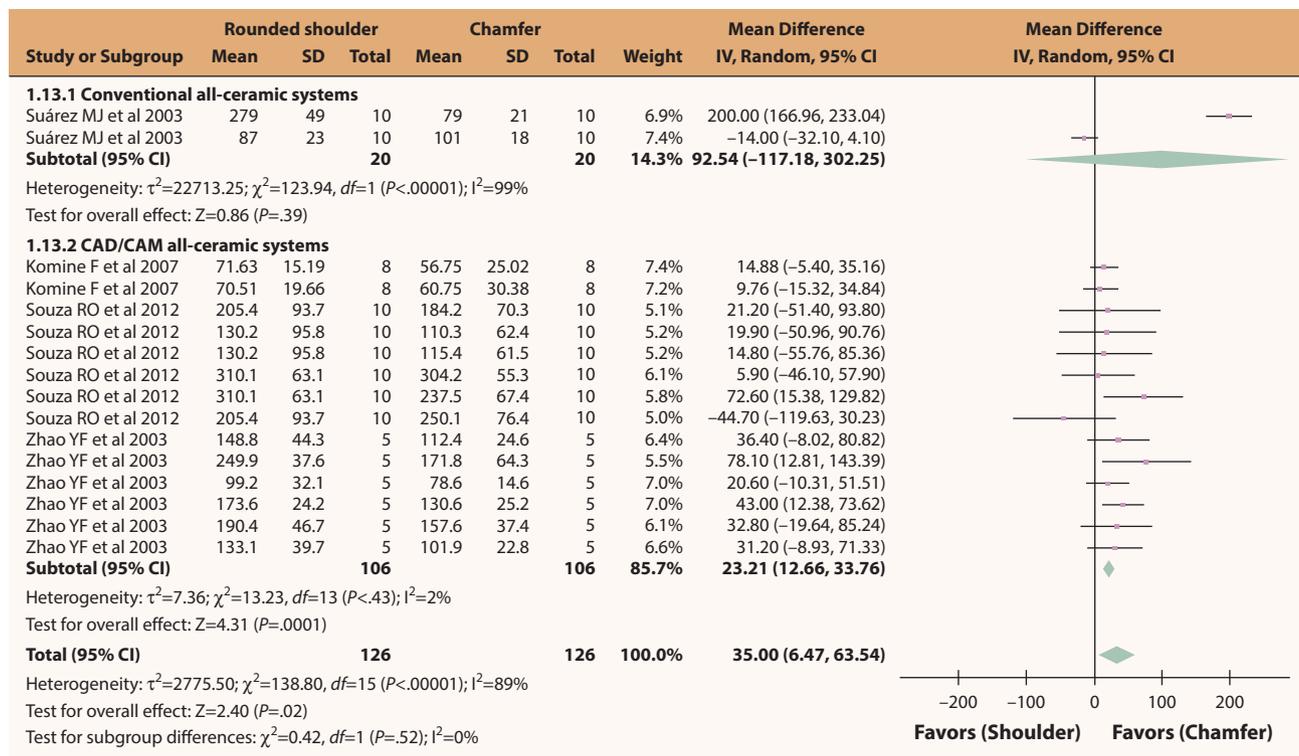
**Supplemental Figure 1.** Forest plot summarizing marginal adaptation of ceramic crowns (subgroup: ceramic system). CAD-CAM, computer-assisted design and computer-assisted manufacturing; CI, confidence interval; SD, standard deviation.



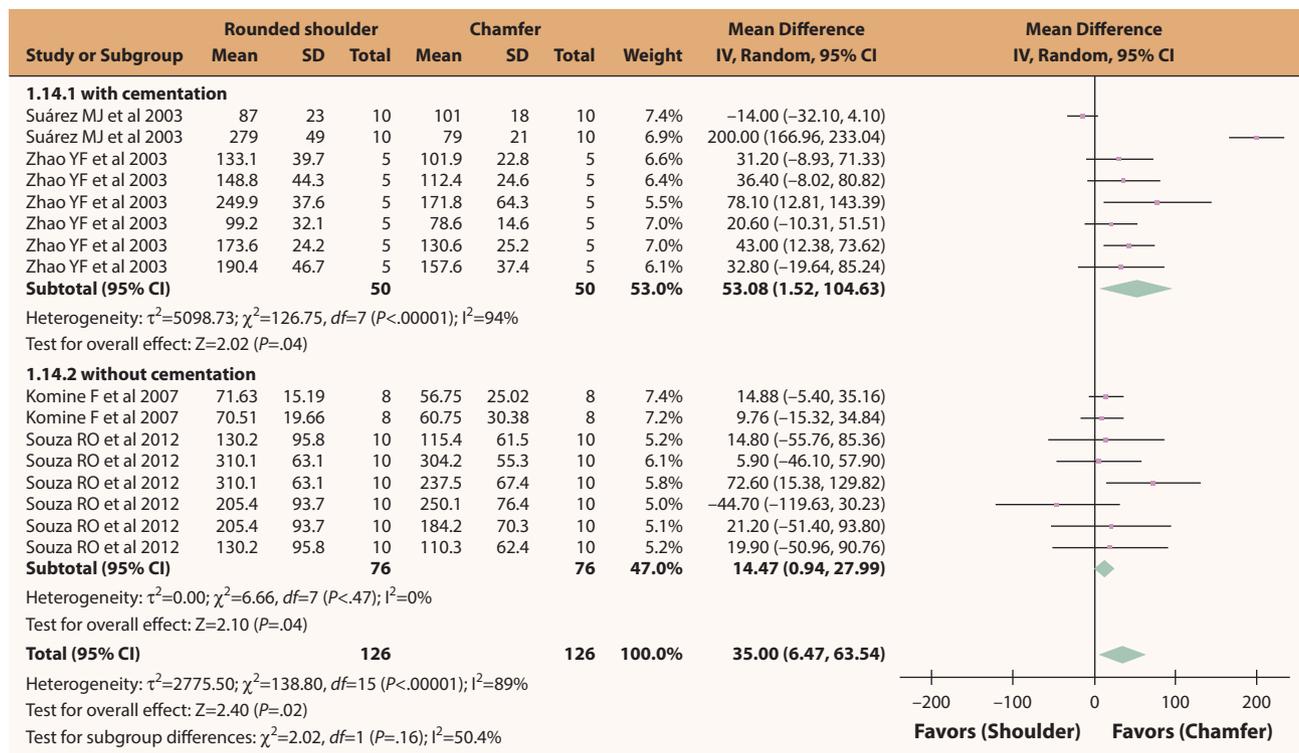
**Supplemental Figure 2.** Forest plot summarizing marginal adaptation of ceramic crowns (subgroup: cementation). CI, confidence interval; SD, standard deviation.



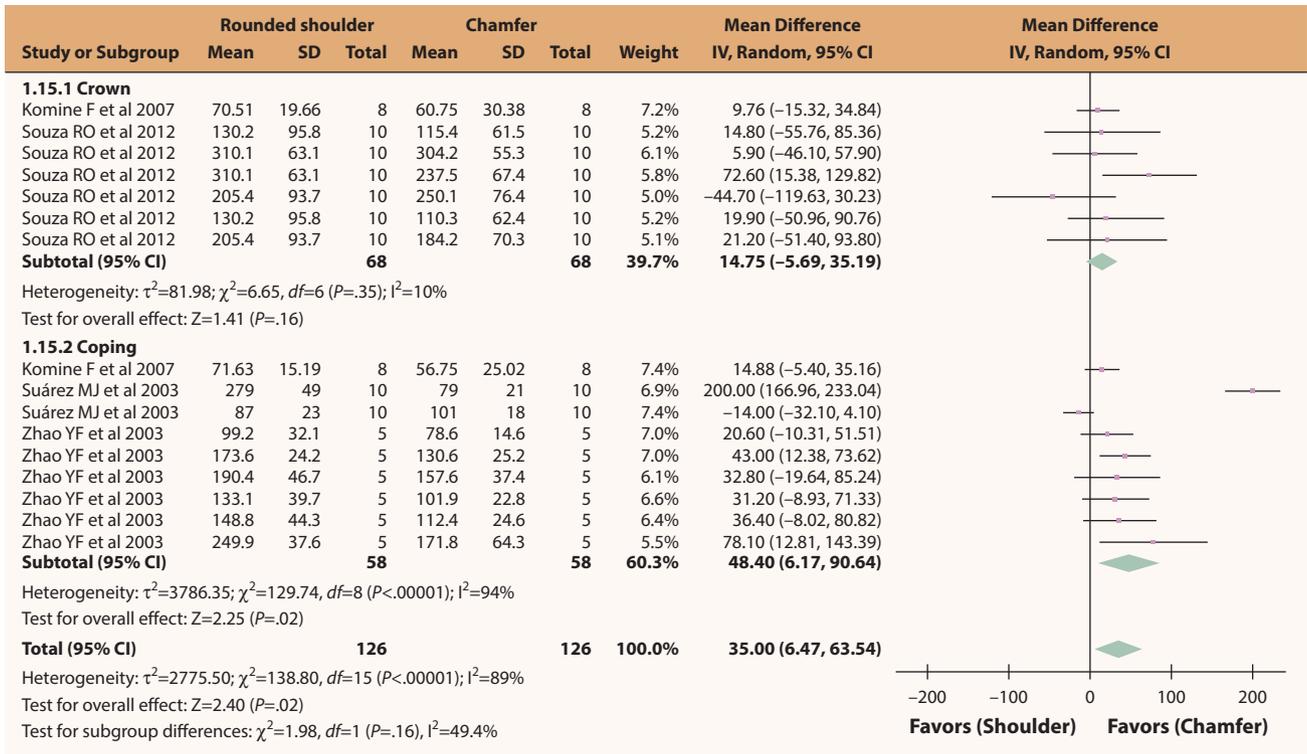
**Supplemental Figure 3.** Forest plot summarizing marginal adaptation of ceramic crowns (subgroup: stage of restoration). CI, confidence interval; SD, standard deviation.



**Supplemental Figure 4.** Forest plot summarizing internal adaptation of ceramic crowns (subgroup: ceramic system). CAD-CAM, computer-assisted design and computer-assisted manufacturing; CI, Confidence interval; SD, standard deviation.



**Supplemental Figure 5.** Forest plot summarizing internal adaptation of ceramic crowns (subgroup: cementation). CI, confidence interval; SD, standard deviation.



**Supplemental Figure 6.** Forest plot summarizing internal adaptation of ceramic crowns (subgroup: stage of restoration). CI, confidence interval; SD, standard deviation.