

# The prosthodontic concept of crown-to-root ratio: A review of the literature

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Crown-to-root ratio is intended to serve as an aid in predicting the prognosis of teeth. However, controversy persists as to its impact on diagnosis and treatment planning. This article critically reviews the available literature on the crown-to-root ratio assessment and criteria for evaluation of abutment use of periodontally compromised teeth. A Medline search was completed for the time period from 1966 to 2003, along with a manual search, to locate relevant peer-reviewed articles and textbooks published in English. Key words used were “crown-to-root ratio,” “periodontal compromised dentition,” “mobility,” and “biomechanics.” There was a dearth of evidence-based research on the topic. Although the use of the crown-to-root ratio in addition to other clinical indices may offer the best clinical predictors, no definitive recommendations could be ascertained. (J Prosthet Dent 2005;93:559-62.)

One of the most common, yet difficult clinical determinations is the prognosis of teeth that may serve as prosthetic abutments. With no definitive criteria to guide the clinician, the treatment plan is based, at best, on heuristic information and clinical experience. Because abutment teeth are subjected to higher than usual occlusal forces transmitted through the prosthesis, the clinician must evaluate the abutment teeth carefully. Some have attempted to establish objective standards for abutment evaluation<sup>1,2</sup> but have not presented evidence-based criteria. The crown-to-root ratio (CRR) is one of the primary variables in the evaluation of the suitability of a tooth as an abutment for a fixed or removable partial denture (FPD or RPD).<sup>1-4</sup> However, abutment mobility, alveolar bone support, root configuration and angulation, opposing occlusion, pulpal condition, presence of endodontic treatment, and the remaining tooth structure have also been cited as predictors for abutment longevity.<sup>5-9</sup>

This literature review investigates the assessment and prosthodontic impact of the crown-to-root-ratio, particularly in regard to periodontally compromised teeth. A search of the peer-reviewed English dental literature from 1966 to 2003 was performed using Medline as well as a hand search of pertinent dental textbooks. Key words used were “crown-to-root ratio,” “periodontal compromised dentition,” “mobility,” and “biomechanics.”

## Definition of crown-to-root ratio

The CRR represents the biomechanical concept of Class I lever for evaluating abutment teeth. The ratio

is defined as “the physical relationship between the portion of the tooth within the alveolar bone compared with the portion not within the alveolar bone, as determined radiographically.”<sup>10</sup> The fulcrum, or center of rotation, of the Class I lever is in the middle portion of the root that is embedded in alveolar bone.<sup>11,12</sup> The CRR may increase over time, primarily as a result of loss of alveolar bone support; the crown portion of the fulcrum (effort arm) would then increase, and the root portion (resistance arm) would decrease. In addition, the center of rotation moves apically, and the tooth is more prone to the harmful effect of lateral forces.<sup>2,6</sup> Increasing the vertical dimension of occlusion to restore the dentition would also cause an increase in the CRR, without altering the root support. Therefore, some authors have suggested that teeth that may serve as abutments and be subjected to increased occlusal loads, such as in patients with extreme vertical overlap and bruxism, should be evaluated with other parameters as well as the measurement of CRR.<sup>6,12</sup>

It is imperative not to confuse the measurements of the anatomical crown, the clinical crown, and the crown for determining the CRR. While the anatomical crown is the portion of the natural tooth that extends from the cemento-enamel junction (CEJ) to the occlusal/incisal edge, the clinical crown is the portion of the crown that extends from the free gingival margin to the occlusal/incisal edge.<sup>10</sup> These definitions provide no information about the amount of the alveolar support, whereas in the CRR, the crown portion is measured in relation to the alveolar bone support.

The CRR definition has several inherent shortcomings. The ratio is based on linear measurements only; however, when evaluating abutment teeth, the clinician should assess the status of the alveolar bone height and the total supported root surface of the abutment tooth.<sup>13</sup> Since most roots have conical shape and the root length is only a 1-dimensional linear measurement, other criteria should be used to evaluate the total

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alveolar support of the abutment. For example, it was found that if one half of the height of attachment to the root was lost due to periodontal disease, a mean of 61.5% of the actual attachment area to the root would be lost.<sup>14</sup> Furthermore, if a mean of 5.72 mm of root attachment height is lost, or if a mean of 60.6% of the same root height remains, only one half of the total root attachment area would remain to provide tooth support.<sup>14</sup> Mowry et al<sup>15</sup> studied the root surface area of mandibular canines and premolars and found that at half of the root length of these teeth, only 38% of attachment remained. The authors also found that increasing attachment loss is related to, but not directly proportional to, decreasing root surface area. In multirooted teeth, the relatively limited area of the root trunk provides more extended surface area than what would appear for bone and fiber attachment.<sup>16</sup> For the maxillary first molar, the mean distance from the CEJ to the point at which the roots separate from the root trunk was 5.0 mm for the mesiobuccal root and 5.5 mm for the distobuccal root.<sup>17,18</sup> However, this area averaged 32% of the total root surface area of the tooth and was significantly greater than that of any of the 3 individual roots.<sup>19</sup> The CRR does not express the actual area of bone support and, therefore, might underestimate the severity of bone loss around the abutment.

Radiographic evaluation has been the most widely used technique in clinical practice for assessing bone level around teeth. However, the CRR definition, as previously stated, does not recommend a preferred radiographic method for determining the ratio. Pepelassi and Diamanti-Kipiotti<sup>20</sup> evaluated methods of conventional radiography for detecting periodontal osseous destruction and suggested that periapical radiography is more successful in assessing periodontal osseous destruction than panoramic radiography. Periapical radiography was more successful than panoramic in the detection of especially small osseous destruction (1-4 mm). Panoramic radiography underestimated the osseous destruction, whereas periapical radiography was relatively accurate in the assessment of this destruction, regardless of the location.<sup>21</sup> Therefore, the radiographic evaluation of the CRR should be based on periapical radiography rather than panoramic.<sup>22</sup> In addition, when using panoramic radiographs to assess bone loss and to determine the CRR, the clinician should use direct measurement from the CEJ to alveolar bone rather than the assessment of the proportion of the tooth length within the bone.<sup>23</sup>

### The value of CRR

When describing and discussing the CRR, prosthodontic literature tends to use vague terms that are open to interpretation, such as “favorable,” “appropriate,” “satisfactory,” “unfavorable,” “poor,” and “unsatisfactory.”<sup>24</sup> A prosthodontic textbook considers

a CRR for an FPD abutment of 1:2 to be ideal, but in practice this is rarely observed.<sup>3</sup> This ratio is based on studies of periodontally healthy subjects for whom the root length and the alveolar bone height are 60% to 70% of the tooth length and the alveolar bone height is 90% or more of the root length.<sup>25,26</sup> Dykema et al<sup>3</sup> suggested a ratio of 1:1.5 as an acceptable and desirable CRR for abutments, although the authors state that the less favorable proportion may be acceptable when the periodontium is in healthy condition and the occlusion is controlled. Teeth with a normal amount of bone support should be used for abutments; however, clinicians should consider teeth with loss of more than one third of the periodontal support to be of questionable value as abutments.<sup>24</sup> Shillingburg et al<sup>1</sup> suggested a 1:1.5 CRR as optimum for an FPD abutment, or a 1:1 ratio as a minimum ratio for a prospective abutment under normal circumstances. The authors also indicated that if the opposing occlusion is composed of tissue-supported prosthesis, a crown-to-root ratio greater than 1:1 might be adequate because of the diminished occlusal forces. Others have suggested that the original 1:2 CRR guideline in the selection of abutments is exceptionally conservative and limits treatment.<sup>27</sup>

### Crown-to-root ratio in clinical practice

Clinical procedures directly affect the CRR. Abutment preparation for overdentures has the most dramatic effect on the ratio, reducing the crown to 1 to 2 mm above the free gingival margin,<sup>28</sup> which can improve the CRR from 1:1 to 1:2 or 1:3. The decrease in crown height shortens the corresponding lever arm length, and therefore, less lateral force is applied to the attachment apparatus, with an apparent reduction of the abutment horizontal mobility.<sup>29</sup> In a longitudinal study of overdenture patients, Renner et al<sup>30</sup> demonstrated that over a 4-year period, 50% of the roots remained immobile, 25% of the roots that were initially mobile exhibited no mobility, and 25% of the roots decreased in mobility. Abutment mobility was correlated to general periodontal health, as well as to the improved biomechanical CRR. Conversely, any increase in the vertical dimension of occlusion (VDO) increases the CRR. No clinical study was identified that evaluated CRR measurements or tooth mobility after the VDO was increased with prosthetic or orthodontic treatments.

Surgical crown lengthening is often necessary to restore teeth that have been compromised by caries, trauma, or extensive wear.<sup>31</sup> Crown lengthening re-establishes the dentogingival junction at a more apical level on the root to accommodate the junctional epithelium and the connective tissue attachment.<sup>32</sup> This procedure increases the CRR. Forced eruption can be used in addition to, or as an alternative to, crown lengthening for teeth with sound tooth structure at or below

the bone crest.<sup>33,34</sup> Continued, slow, passive or active orthodontic eruption, in rates of approximately 2 mm per month, allows the periodontal ligament to repair and the alveolar bone to remodel between orthodontic adjustments. Hence, slow, forced eruption is preferred to surgical removal of supporting alveolar bone because it preserves the biologic width and, at the same time, provides better CRR.<sup>35-37</sup>

### Splinting and crown-to-root ratio

Periodontal bone loss around abutments results in an increased CRR that is associated with increased tooth mobility.<sup>38</sup> However, increased mobility is not always found with teeth showing increased CRR.<sup>39</sup> Different periodontal treatment modalities that resolve the inflammatory process may result in reduced tooth mobility without changing the previously reduced alveolar bone support.<sup>40</sup> Investigators<sup>7,38</sup> have demonstrated the long-term success of periodontally compromised abutment teeth that supported extensive cross-arch FPDs. The exact CRR of these abutments was not calculated, but no mechanical failure of abutment teeth was attributed to the increased CRR. The prosthodontic concept of splinting teeth, especially abutments, evolved from the need to compensate for the increased CRR.<sup>12</sup> Splinting abutments may enhance stability and may shift the center of rotation and transmit less horizontal force to the abutments.<sup>41</sup> However, some *in vitro* studies do not support this theoretical model.<sup>42,43</sup>

Itoh et al,<sup>42</sup> using a photoelastic model, evaluated the effects of periodontal support and fixed splinting on load transfer by RPDs. The authors found that increasing the number of splinted teeth did not provide a proportional decrease in maximum stress levels and stated that routine cross-arch splinting may not be appropriate. Using a photoelastic model, Wylie and Caputo<sup>43</sup> evaluated the stresses that cantilever FPDs developed in teeth and supporting bone where the most distal abutments had osseous defects and hence increased CRR. The authors found that for a cantilever FPD with either normal periodontal support or a distal abutment with a moderate degree of mobility and bone loss, the occlusal forces were significantly distributed to only the 3 teeth closest to the loaded cantilever. Moreover, increasing the number of splinted abutments beyond 3 did not result in a proportional reduction of stress in the periodontium, and no significant cross-arch sharing of occlusal loads was seen. No objective criteria were identified in the literature to define the need or extent of splinting in relation to the abutment CRR, and the effect of splinting on abutment longevity has not been established. Therefore, when evaluating the need for splinting of periodontally compromised teeth, the clinician should consider other predictive indices, such as the presence of increasing mobility, initial probing depth, initial furcation involve-

ment, patient ability to maintain optimal oral hygiene, presence of a parafunctional habit without the use of an occlusal stabilization device, and tobacco use.<sup>6,7,44</sup>

### Crown-to-root ratio as a prognostic tool

The primary objective in evaluating clinical criteria for abutments and periodontally compromised teeth is to determine the best prognosis. The clinician identifies objective findings that can predict the prognosis of teeth as abutments. Abutment teeth may or may not require more rigid standards due to increased functional demands.<sup>44</sup> McGuire and Nunn<sup>45</sup> evaluated 100 periodontally treated patients (2,484 teeth) under maintenance care for 5 years (with 38 of these patients followed for 8 years) to determine the relationship of assigned prognoses to the clinical criteria commonly used in the development of prognosis. The authors classified teeth as having either a favorable or unfavorable CRR, although no numeric measurement was mentioned. Unsatisfactory CRR and teeth used as fixed abutments were among the clinical factors that resulted in worse initial prognoses. The coefficients calculated from the suggested model were able to accurately predict the 5-year and 8-year prognoses 81% of the time. None of the examined factors, including the CRR, was significant in worsening the prognosis; the assignment of prognosis was ineffective for teeth with an initial prognosis of less than "good." Nevertheless, the presence of an unsatisfactory crown-to-root ratio was identified as one of the significant clinical factors for clinicians to consider.<sup>45</sup>

## DISCUSSION

As a suggested clinical guideline for the evaluation of abutment teeth, the clinician should use the crown-to-root ratio only with other multiple clinical parameters, such as abutment mobility, total alveolar bone support, root configuration, opposing occlusion, presence of a parafunctional habit, pulpal condition, presence of endodontic treatment, and the remaining tooth structure. The total remaining periodontal bone support provides more accurate information than the linear measurement of the ratio, which is limited even in the prediction of the prognosis of nonabutment teeth. Therefore, indications other than the crown-to-root ratio should be used to determine whether splinting of teeth is appropriate.

Confounders make it impossible to isolate a single clinical parameter, such as CRR, from others in *vivo* studies. However, long-term prospective clinical studies are required to identify the exact prognostic value of each clinical requirement for abutments. Future research should concentrate on predictive indices that will assist the clinician in deciding whether to preserve compromised teeth or place implants.

## SUMMARY

There is a lack of consensus and evidence-based research on the influence of crown-to-root ratio on diagnosis and treatment planning for periodontally compromised teeth. It appears that multiple factors may play a role in determining the prognosis of abutments considered for support of a fixed or removable prosthesis.

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0022-3913/\$30.00

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doi:10.1016/j.prosdent.2005.03.006