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REVIEW ARTICLE

VALIDITY OF CROWN-TO-ROOT RATIO AS A PROGNOSTIC TOOL IN CLINICAL PRACTICE

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ABSTRACT: The relationship between the portion of the tooth coronal to the alveolar crest of bone compared with the portion embedded in it, has always been regarded as a vital 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 the shift in paradigm related to the criteria for evaluation of abutment use of periodontally compromised teeth. Also various treatment modalities present to improve an unfavourable crown-to-root ratio have been stated. A Medline search was completed for the time period from 1961 to 2005, along with a manual search to locate relevant peer reviewed articles and textbooks published in English. There was a scarcity of evidence-based research on the topic. Although the use of crown-to-root ratio along with other clinical indices may offer the best clinical predictors, no definite recommendations could be ascertained.

KEYWORDS: biomechanics, crown-to-root ratio, mobility, periodontally compromised dentition.

INTRODUCTION: Every restoration must be able to withstand the constant occlusal forces to which it is subjected. This is of particular significance when designing and fabricating a fixed partial denture, since the forces that would normally be absorbed by the missing tooth are transmitted, through the pontic, retainers and connectors to the abutment teeth; in addition to those that are usually applied to the abutments.[1] These forces are then transmitted through the abutments to the periodontium. Failures of fixed partial dentures are usually due to poor engineering, use of improper materials, inadequate tooth preparation and faulty fabrication. Successful selection of abutments hence assumes utmost importance requiring sensitive diagnostic ability on the part of the dental practioner.[2]

With no definitive criteria to guide the clinician, the restorative treatment plan is based, at best, on heuristic information and clinical experience. Various attempts have been made to establish objective standards for abutment evaluation,[1,3,4] but an evidence-based criteria has not been presented till date. A careful evaluation of factors considered as predictors for abutment longevity involve examining the prospective abutment for mobility, alveolar bone support, root configuration and angulation, opposing occlusion, pulpal condition, presence of endodontic treatment, and remaining coronal tooth structure.[2,4,5-8] Nonetheless, the crown-to-root ratio is one of the primary variables and considered as the first factor in abutment evaluation.[1,3,4,9-11]

DEFINITION AND HISTORICAL PERSPECTIVE: The crown-to-root ratio usually thought of, as the proportion between the clinical crown and clinical root, represents the biomechanical concept of a class I lever for evaluating abutment teeth.[4,12] It is a measure of tooth stability as it provides valuable information regarding resistance against leverages of oral forces;[9,12] the nature of this leverage depending upon the amount of tooth retained in alveolar bone i.e clinical root.[9]

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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.''[13] (Figure 1)

In simple terms, crown-to-root ratio is the ratio of the respective tooth parts. It is important to differentiate between anatomic and clinical aspects of this relationship. 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.[4,13,14] (Figure 2) Contrary to its description given in old literature,[3,9,10,12,14] which provides no information about the amount of the alveolar support, the definition stated in GPT VII describes the crown portion in relation to the alveolar bone support.[4]

HOWEVER, THE CRR DEFINITION HAS SEVERAL INHERENT SHORTCOMINGS.[4]

A. The ratio is based on linear measurements on a 2-dimensional radiograph only; however, when evaluating abutment teeth, the clinician should assess the status of alveolar bone height 3-dimensionally along with the total supported root surface of the abutment tooth.[4,15] Since most roots have conical shape and the root length is only a 1-dimensional linear measurement, a more comprehensive investigation would reveal conflicting results.[4,16-21] Thus, the CRR does not express the actual area of bone support and, therefore, might underestimate the severity of bone loss around the abutment.[4]
B. Also the definition entails radiographic examination as the method in clinical practice for assessing bone levels around teeth and thereby the CRR. However, it fails to recommend a preferred radiographic method for determining the ratio. Recent comparative studies evaluating methods of conventional radiography for detecting periodontal osseous destruction have suggested periapical radiography as a more successful tool in assessing osseous defects as small as 1-4mm than panoramic radiography regardless of its location.[22,23] Therefore, the radiographic evaluation of the CRR should be based on periapical radiography rather than panoramic.[24] 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.[25]

CLINICAL RELEVANCE OF CRR: Analogous to a class I lever, the fulcrum, or center of rotation, is in the middle portion of the root that is embedded in alveolar bone.[4,26,27] (Figure 3a) Now, poor crown-to-root ratio can result from improper dental treatment as well as from traumatic or pathologic changes that either increase the length of the clinical crown or decrease the length of the clinical root. However, the most common cause of poor (Increased) crown-to-root ratio is periodontitis.[14] Since the prevalence and severity of periodontitis increases with age, problems in crown-to-root ratio are usually associated with an adult population.[14] Nonetheless, such a clinical change would directly cause the crown portion of the fulcrum (Effort arm) to increase, and the root portion (Resistance arm) to decrease. In addition, the center of rotation will shift apically, and the tooth will be more prone to the harmful effect of lateral forces.[3,4,5] (Figure 3b) All of these would directly lead to a plethora of clinical adversities such as mobility,[6] development of dental caries on exposed root surfaces especially mandibular premolars,[28] and dentinal hypersensitivity.[14]

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At the same time, increasing the vertical dimension of occlusion in cases of full-mouth rehabilitation would also cause an increase in the CRR, without altering the root support.
(Figure 4a, 4b,4c)

Hence it is imperative that teeth that may serve as abutments and be subjected to increased occlusal loads, such as in patients with extreme vertical overlap and bruxism, be evaluated with other parameters as well as the measurement of CRR.[4,5,27]

CLINICAL TERMINOLOGIES ASSOCIATED WITH CRR: The literature while describing CRR tends to use vague terms that are open to interpretation, such as ''favorable,'' ''appropriate,'' ''satisfactory,'' ''unfavorable,'' ''poor,'' and unsatisfactory[9]. The early guidelines on crown-to-root ratio of 1:2 for abutment teeth were conservative and limited treatment modalities, but they still serve as a standard in many texts.[2,9,10,29,30,31] (Figure 5a) These guidelines were primarily 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.[4,32,33] Recently Dykema et al and Shillingburg et al suggested a 1:1.5 CRR as optimum and acceptable for an FPD abutment provided periodontium is in healthy condition and the occlusion is controlled.[1,10] Although a CRR of 1:1 is regarded as a minimum ratio[2,3] for prospective abutments under normal circumstances, a ratio greater than 1:1 might be adequate if the opposing occlusion is composed of tissue-supported prosthesis.[1]

On the other hand, abutments that exhibit loss of more than one third of the periodontal support are deemed to be of questionable value as abutments.[9] Also, teeth with extensive bone loss with only one third of the apical bone remaining, and a true pocket depth greater than 6 to 7 mm, are sometimes considered hopeless and assigned a poor prognosis.[14,34]
(Figure 5b)

CRR IN DAILY CLINICAL PRACTICE (FIGURES 6A TO 6D, 7A AND 7B):

1. **Procedures that result in decreased 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, can improve the CRR from 1:1 to 1:2 or even 1:3.[35] This shortens the corresponding lever arm length, and therefore, less lateral force is applied to the attachment apparatus, with an apparent reduction of the abutment mobility horizontally.[36,37] (figure 6a, 6b, 6c and d)
2. **Procedures that result in increased CRR:** Unrestorable teeth that have been compromised by caries, trauma, or extensive wear require surgical crown lengthening to increase the length of clinical crown before fixed prosthodontic therapy can be initiated.[4,38] (figure 7a and 7b) However, continued, slow, passive or active orthodontic eruption, in rates of approximately 2 mm per month[4] is preferred to surgical removal of supporting alveolar bone as it preserves the biologic width and, at the same time provides better CRR.[39,40,41]
3. **CRR and Splinting:** It has been already established that Periodontal bone loss around abutments results in an increased CRR that may or may not be associated with increased tooth mobility.[42,43] Different periodontal treatment modalities that resolve the inflammatory process may result in reduced tooth mobility without changing the previously reduced alveolar bone support and hence CRR.[4,44] Nonetheless, the concept of splinting periodontally compromised abutments

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evolved from the need to compensate for the increased CRR.[27] (figure 6d) Splinting abutments may enhance stability and may shift the center of rotation and transmit less horizontal force to the abutments.[45] However, some in vitro studies do not support this theoretical model.[46,47]

Also, Dawson emphasized the difficulty in maintaining good oral hygiene in splinted areas and suggested splinting only when it is needed.[48]

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.[4] Hence when evaluating the need for splinting periodontally compromised teeth, the clinician should best consider other predictive indices to arrive at a conclusion.[4]

POOR CRR AND BEYOND: Once a sound clinical decision has been made after a thorough investigation of prognosis of a prospective abutment, a logical treatment plan should be finalised and if the CRR is deemed to be less, then following treatment considerations need to be taken into account to improve the longevity of the tooth:

1. **Plaque control and adequate oral Hygiene:** Plaque control and adequate oral hygiene are of primary concern in teeth having poor crown-to- root ratio. Continued progression of periodontitis due to inadequate plaque control invites treatment failure;[15,34,49] as do structural changes resulting from faulty restorative procedures such as poor margin placement, over-contoured crowns etc.[14]
2. **Regenerative periodontal Surgery:** Regeneration of lost periodontal support is the most logical approach to improve poor crown-to-root ratio, and bone grafting is the most reliable method. Ingber[50] presented the rationale and technique of forced eruption coupled with occlusal reduction and regenerative surgery as a method of treating one- and two-wall infrabony defects.
3. **Occlusal Reduction:** Reducing clinical crown length by occlusal reduction of extruded teeth is a valid approach to improving the crown-to-root ratio. However, many a times it has to be done in conjunction with intentional pulp extripation and a reduction of even a 1mm of posterior vertical stop(vertical dimension of occlusion), can cause an increase of 3 mm of anterior vertical overlap(overbite).[51]
4. **Increasing stability of the Dentition:** The mobility seen in teeth with poor crown-to-root ratio can be reduced by selectively grinding occlusal surfaces as natural teeth are designed to better resist axially directed forces.[6,52]

EXTRACTION OF HOPELESS TEETH–THE LAST RESORT!: Generally, any noncritical tooth with serious periodontal liability should be removed. Saxe and Carmen[14,53] have suggested the following as the indications for removal of problem teeth:

1. An unopposed terminal tooth in an arch.
2. A periodontally involved tooth with sound adjacent teeth providing other treatment alternatives, and/or (Figure 8).
3. A solitary distal abutment that exhibits mobility.

AT THE SAME TIME, SOME SERIOUSLY INVOLVED TEETH MAY BE RETAINED[53] IF:

1. An involved terminal tooth in an arch is the antagonist for a sound tooth (figure 9), and
2. A solitary tooth will serve as an abutment.

DISCUSSION: Value of CRR as a prognostic tool. The primary objective in evaluating clinical criteria for abutments and periodontally compromised teeth is to determine the best prognosis. A wide range of clinical parameters including CRR are available to the dental practioner for the evaluation of the same.[4] However, confounders make it impossible to isolate a single clinical parameter, such as CRR, from others in vivo studies.[4] McGuire and Nunn[54] 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 and classified teeth as having either a favorable or unfavorable CRR. Unsatisfactory CRR and teeth used as fixed abutments were among the clinical factors that resulted in worse initial prognoses but none of the examined factors, including the CRR, was significant in worsening the prognosis. Nevertheless, the presence of an unsatisfactory crown-to-root ratio was identified as one of the significant clinical factors for clinicians to consider.[54]

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 prospective abutment teeth. It appears that multiple factors may play a role in determining the prognosis of abutments and future research should concentrate on predictive indices that will assist the clinician in deciding whether to preserve compromised teeth or extract them and place implants.

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FIGURE 1: An IOPA of a molar depicting the Crown-to-root ratio in accordance with the radiographic guidelines. Clearly, CRR is deemed as unfavourable as shown in the figure.

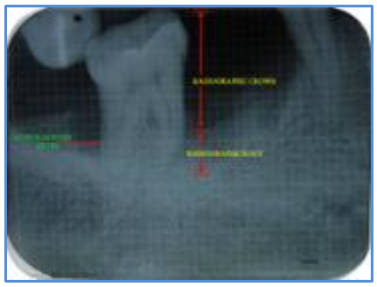

FIGURE 1

FIGURE 2: Mandibular canine with severe bone loss demonstrating the contrast between anatomic and clinical crown-to-root ratio.

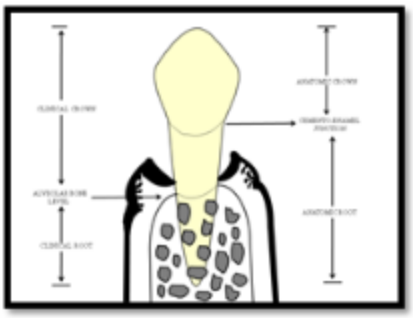

FIGURE 2

Figure 3a: An illustration to demonstrate the analogy of a class I lever action for a healthy tooth with the actual centre of rotation (C) lying at the junction of middle and apical thirds of the root length. Note the effort arm ($E_{0)}$ and resistance arm (R_0).

Figure 3b: An illustration which shows apical migration of the centre of rotation as a consequence of periodontitis and loss of attachment. Note the apparent effort arm which is now expressed as a sum of E_0 and E', where E' is the distance by which the fulcrum migrates apically.

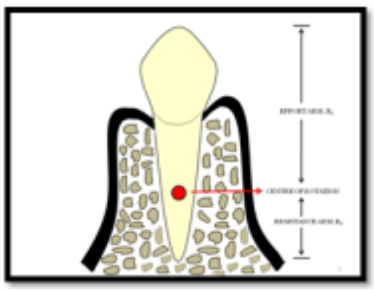

FIGURE 3a

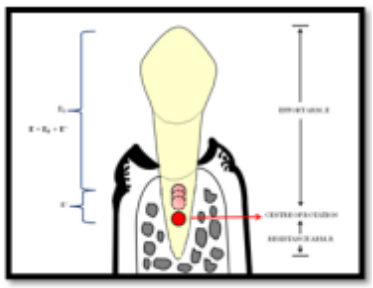

FIGURE 3b

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Figure 4a: Frontal view of a patient's dentition which shows localised gingival recession generalised interdental spacing and loss of vertical dimension of occlusion. Any attempt to increase VDO will result in increase in clinical crown height and consequently, an increased CRR.

Figure 4b and 4c: Maxillary and mandibular occlusal views of the same patient demonstrating the deleterious effects of wasting disease in the form of wear facets, dentinal exposure and resultant loss of vertical dimension of occlusion.

FIGURE 4a

FIGURE 4b

FIGURE 4c

Figure 5a: An illustration demonstrating an ideal crown-to-root ratio of 1:2 with minimal evidence of alveolar crestal bone loss. Such a situation is a clinical rarity and is considered conservative as it limits the treatment options available.

Figure 5b: An IOPA of a mandibular molar which demonstrates extensive vertical alveolar bone loss with only 1/3rd of the root embedded in bone. Prognosis of this tooth as an abutment is deemed questionable/hopeless. However, a more detailed periodontal evaluation will give a more predictable indication of prognosis of this prospective abutment.

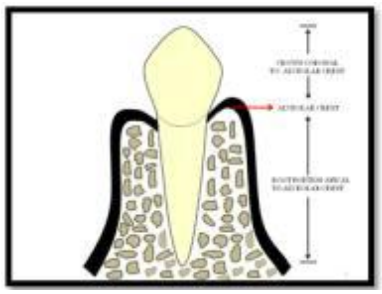

FIGURE 5a

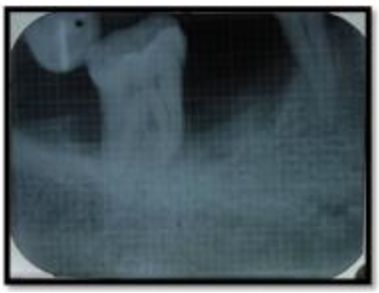

FIGURE 5b

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Figure 6a: Initial presentation of the case with maxillary and mandibular acrylic removable partial dentures, few remaining teeth in both the arches, gingival recession (increased CRR) in maxillary anterior segment with interdental spacing.

Figure 6b: Preliminary phase of treatment showing orthodontic repositioning being carried out to close interdental spaces and provide favourable force distribution. Also, note the widely spaced quadrilateral arrangement of remaining mandibular teeth considered typical for an overdenture.

FIGURE 6a

FIGURE 6b

Figure 6c: Note the drastic reduction in the CRR of remaining mandibular teeth after abutment preparation for an overdenture.

Figure 6d: Orthodontic wire placed lingually in relation to maxillary anteriors which serves to act both as a retainer at the termination of orthodontic therapy and a splint to compensate for increased CRR.

FIGURE 6c

FIGURE 6d

Figures 7a and 7b: Mandibular occlusal and lateral views showing gross destruction of coronal tooth structure of mandibular molar and premolar respectively requiring surgical crown lengthening, resulting in an increased CRR, before the institution of restorative therapy.

FIGURE 7a

FIGURE 7b

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Figure 8: An OPG showing lone standing unopposed terminal maxillary molar with extensive bone loss, clearly an indication for its extraction.

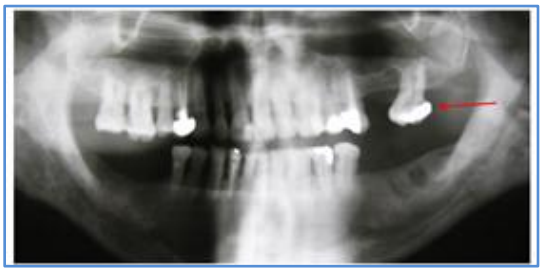

FIGURE 8

Figure 9: An OPG which shows a solitary terminal mandibular molar with radiographic evidence of periodontal involvement, but which is opposed by a sound maxillary molar; thus warranting its retention in the arch.

FIGURE 9

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