Importance of Crown to Root and Crown to Implant Ratios

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**Importance of Crown to Root and Crown to Implant Ratios**

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**LEARNING OBJECTIVES**

After reading this article, the individual will learn:

- The clinical importance of crown to root ratios (CRRs) and crown to implant ratios (CIRs).
- Suggestions for restoring teeth and implants based on a search of the literature focusing on CRRs and CIRs.

**ABOUT THE AUTHORS**

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**INTRODUCTION**

Historically, crown to root ratios (CRRs) of teeth were used as a parameter to help decide if teeth should be restored with or without splinting to adjacent teeth or employed as abutments in dental prostheses. However, guidelines were based upon empiricisms rather than scientific data. This resulted in teeth being extracted that could have been retained. With respect to dental implants, the desire to reduce crown to implant ratios (CIRs) could result in an area being unnecessarily bone augmented to provide additional support for a longer implant. Therefore, it would be advantageous if an assessment of the dental literature provided guidance as to the survival of restored teeth and implants with elevated crown to root or CIRs.

Fixed denture prostheses (FDPs) can be retained by teeth, dental implants, or a combination of both. In either scenario, a FDP needs an adequate number and size of abutments to provide support for a restoration. The number of abutments to retain a prosthesis is dependent on numerous clinical variables, including size and design of the prosthesis, number of missing teeth, occlusal and parafunctional forces, opposing dentition, amount of available bone around abutments, and cost. With respect to providing adequate support for a prosthesis, the issue of root or implant length needs to be considered.

The objective of this article is to discuss the importance of CRRs and CIRs based on a search of the literature focusing on 4 overlapping topics: (1) relevance of Ante’s law to reconstructive dentistry, (2) CRR and CIRs, (3) the utility of short versus long dental implants, and (4) the concept of vertical cantilevers.

**ANTE’S LAW**

In 1926, it was suggested that the total periodontal membrane area of abutment teeth must equal or exceed the membrane area of teeth to be replaced.¹ This was referred to as Ante’s Law, but it actually was an opinion that was never scientifically validated. Unfortunately, application of this concept precluded employing numerous teeth as abutments, because they had lost periodontal support. Thus, teeth were extracted that might have had a better prognosis than expected.² In this regard, a systematic review (6 publications) by Lulic, et al³ surveyed the literature from 1966 to 2006. They evaluated the survival of FDPs when periodontally healthy teeth whose periodontium was severely reduced were incorporated into prostheses. To be included in the review the restorations had to be in
function for 5 years. While not specifically stated in the text, it is reasonable to presume that teeth with reduced periodontiums incorporated into FDPs often demonstrate increased CRRs. Lulic, et al\(^3\) reported that among 579 FDPs, the survival rate was 96.4% and 92.9% after 5 years and 10 years, respectively. These findings are similar to data concerning survival of FDPs fabricated on teeth with good periodontal support.\(^4,5\)

In summary, considering the data from long-term clinical trials, it can be concluded that the concept referred to as Ante's Law with respect to teeth has been refuted. Furthermore, since teeth and implants are retained by 2 different mechanisms (periodontal ligament versus osseointegration), the concept of extrapolating guidelines for patient care with one type of support to the other would be inappropriate.

CROWN TO ROOT RATIOS AND CROWN TO IMPLANT RATIOS

Teeth

Frequently, the CRR is used to determine if a tooth could function as a suitable abutment. The term refers to a ratio calculated from a radiograph with respect to length of the tooth not within bone divided by the portion of the tooth in alveolar bone.\(^6\) When forces are applied to a single-rooted tooth with a complete periodontium, the tooth's center of rotation, or fulcrum, is in the center of the root, two thirds down the root within the bone.\(^6\) The main reason for increased CRRs is fabrication of taller crowns on teeth or pontics subsequent to alveolar bone loss. This results in the crown portion of the prosthesis providing a greater lever arm and the root providing less resistance. When there is additional bone loss, the center of rotation moves apically.\(^6\)

With regard to CRRs discussed in the literature, a variety of ratios were reported. Ideally, the ratio should be 1:2 or 0.5; however, this is rarely seen in clinical practice.\(^7\) Dykema, et al\(^7\) indicated that a CRR of 1:1.5 is desirable. Similarly, Shillingburg, et al\(^8\) suggested a 1:1.5 ratio as most favorable for an abutment and a CRR of 1:1 as a minimum for a tooth abutment. Several procedures alter the CRR as follows: overdentures with a small attachment\(^9\) and extrusion of teeth to provide additional bone both decrease the CRR, whereas an increase in vertical dimension of occlusion and surgical crown lengthening or ridge reduction to make room for an implant abutment increase the CRR.\(^6\) After assessing the literature, Grossmann and Sadan\(^6\) concluded that no definitive recommendations could be established for an optimal CRR concerning teeth.

To compensate for increased forces on prostheses due to increased CRRs, clinicians have splinted teeth together.\(^10\) This may shift the center of rotation and transmit less horizontal forces to individual abutments or alter the response to the applied forces.\(^11,12\) However, no objective criteria exist to define the need or extent of splinting to assuage the effect of an increased CRR.\(^13\)

Dental Implants

A consensus conference defined a desirable crown height space for a fixed prosthesis to be between 8 to 12 mm (bone level to opposing dentition).\(^14\) This height leaves 3 mm for soft tissue (includes biologic width and soft-tissue coverage of implant collar), 2 mm for occlusal porcelain, and an abutment ≥ 5-mm high. However, it was cautioned as the height of the prosthesis increases there is increased risk of component and material fracture due to elevated forces on the restoration.\(^14\) Therefore, increased crown height should be considered as a factor that can affect clinical outcomes both technically and biologically.

In this regard, a projected increased CIR can be reduced by increasing the bone height surgically with ridge augmentation or distraction osteogenesis. On the other hand, if increased CIRs were proven to be safe to use, it would provide a variety of advantages including avoiding some guided bone regeneration procedures, abridged treatment time, facilitating a greater number of patients to be treated, and decreased fees. Therefore, the literature was searched to determine if increased CIRs enhance therapy or induce additional stress that eventually has a deleterious effect on bone adjacent to implants supporting prostheses or prostheses' components.

PERFORMANCE OF IMPLANTS WITH RESPECT TO CROWN TO IMPLANT RATIOS

An elevated CIR has been described as a type of non-axial loading, which can detrimentally affect a prosthesis
Ten studies were found in the dental literature that addressed the survivability of implants in relation to CIRs (Table 1). Seven investigations are succinctly addressed, because they all have different characteristics; the latter 3 pertain to cantilevered prostheses and the data are summarized in Table 1.

Schulte et al. assessed survival of 889 restorations in more than an average of 2.3 years (range 0.1 to 7.4 years). The average survival rate was 98.2%, and these implants (Bicon) had a mean CIR of 1.3 (range 0.5:1 to 3:1). More than 400 prostheses had a CIR ≥ 1.2. Among the 889 restorations that were monitored, 16 implants failed, and these prostheses manifested a mean CIR ratio of 1.4. Similarity of CIRs between failed and successful implants implies that the crown to implant ratio was not a critical determinant with respect to implant survival.

Concerning the relationship between CIR and bone loss around implants, Tawil and Younan evaluated 262 machined surfaced implants (Brånemark) in 109 patients in more than 53 months. Bone loss was not related to CIRs and the survival rate of restored implants was 99.9%. The reported CIRs and the number of cases (in brackets) were as follows: <1 (30), 1 to 1.2 (70), 1.21 to 1.4 (58), 1.41 to 1.6 (29), 1.6 to 2.0 (39) and ≥2 (8).

Blanes et al. appraised the impact of CIRs on the survival of rough surfaced implants (N = 142, Straumann implants) in more than a 10-year period. They divided the patients into 3 groups with respect to CIR: 0 to .99, 1 to 1.99, and ≥2. The mean clinical CIR was 1.77 and increased CIRs were not found to be associated with additional bone loss. The success rate with a CIR of >2 was 94.1% (48 of 51 implants). They concluded that implant restorations with a CIR between 2 and 3 could be successfully used in posterior regions of the dentition. However, it should be noted that the majority of these implants were splinted (81.3%), which furnished an improved distribution of forces between implants.

The impact of CIRs pertaining to bone loss around sintered porous surfaced implants (Endopore) was evaluated by Rokni et al. They monitored (N = 198) implants for 4 years that were 5- to 7-mm long (short implants) and implants 9- to 12-mm long (long implants). Overall, implant restorations had a 1.5 CIR and demonstrated a 98.2% survival rate. The range of CIRs was 0.81 to 3:1. The percentage of implants with a CIR between 1.1 and 2 was 78.9%. Implants with a CIR >2 (n = 20) were followed for approximately 3 years. Different sized implants had the following CIRs (indicated in brackets): 5 mm (2.6), 7 mm (1.8), 9 mm (1.4) and 12 mm (1.0). There were no statistically significant relationships between CIRs and bone loss. The data underscored that short implants with a sintered surface which manifested elevated CIRs did not result in their failure or bone loss.

Nedir et al. reported after a 7-year monitoring period that the survival rate of short (< 10 mm) and longer implants (Straumann implants) (10 to 13 mm) (N = 276) used to support single crowns or short prostheses were 100% and 99%, respectively. They provided the CIR for each length of implant and the number of placed implants: 6-mm long, CIR-1.97, n = 6; 8-mm long, CIR-1.59, n = 97; 9-mm long, CIR-1.55, n = 8; 10-mm long, CIR-1.3, n = 194; 11-mm long, CIR-1.17, n = 71. In general, these data corroborated the predictable use of short implants to support prostheses. However, note that 6-mm implants were splinted to longer implants to support prostheses. In contrast, Rossi et al. monitored for 2 years 35 patients who received a total of 40, 6-mm long implants (Straumann) (19 with a 4.1-mm diameter; 29 with a 4.8-mm diameter) that were not splinted together. Their mean implant CIR was 1.5 (range 0.8 to 2.3) and the implant survival rate was 95%. The mean bone loss...
for implants that lost bone (29 of 38 implants) between loading and the 2-year follow-up was 0.43 mm. Two implants failed and were removed before restorations were placed. Recently, Urdaneta, et al. assessed the effect of increased CIR with respect to bone loss and other prosthetic complications. In more than a 70-month period, they

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Implants</th>
<th>CIR</th>
<th>Percent Survivability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schulte, et al.¹⁷</td>
<td>889</td>
<td>1.3 mean</td>
<td>98.2%</td>
</tr>
<tr>
<td>Tawil and Younan.¹⁸</td>
<td>262</td>
<td>a</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>&lt; 1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>1 to 1.2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>58</td>
<td>1.2 to 1.4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>1.4 to 1.6</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>39</td>
<td>1.6 to 2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>&gt; 2</td>
<td>-</td>
</tr>
<tr>
<td>Blanes, et al.¹⁹</td>
<td>8</td>
<td>1.77 mean</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>133</td>
<td>0 to 0.99</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>1 to 1.99</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>91.4%</td>
</tr>
<tr>
<td>Rokni, et al.²⁰</td>
<td>22</td>
<td>1.5 mean</td>
<td>98.2%</td>
</tr>
<tr>
<td></td>
<td>156</td>
<td>0.8 to 1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1.1 to 2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 2</td>
<td>-</td>
</tr>
<tr>
<td>Nedir, et al.²¹</td>
<td>111</td>
<td>1.55 to 1.97</td>
<td>100</td>
</tr>
<tr>
<td>Rossi, et al.²²</td>
<td>40</td>
<td>1.5 mean</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>range 0.8 to 2.3</td>
<td>-</td>
</tr>
<tr>
<td>Urdaneta, et al.²³</td>
<td>326</td>
<td>1.6 mean</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>≥ 2</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>206</td>
<td>1.0 to 1.99</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>&lt; 1.0</td>
<td>-</td>
</tr>
<tr>
<td>a mean CIR for all the implants was not provided, survival percentage is for all groups combined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b survival rates only provided for CIRs ≥ 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c CIR was computed related to specific implant lengths—6-mm long, CIR-1.97, n = 6; 8-mm long, CIR-1.59, n = 97; 9-mm long, CIR-1.55, n = 8, 10-mm long.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Implants</th>
<th>CIR</th>
<th>Mean Length of Implants or Range of Sizes</th>
<th>Percent Survivability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wennstrom, et al.²⁴</td>
<td>68</td>
<td>1.60</td>
<td>12.7</td>
<td>97%</td>
</tr>
<tr>
<td>Brägger, et al.²⁵</td>
<td>33</td>
<td>1.84</td>
<td>not recorded</td>
<td>98.4%</td>
</tr>
<tr>
<td>Hälg, et al.²⁶</td>
<td>46</td>
<td>1.65</td>
<td>6 to 12 mm</td>
<td>95.7%</td>
</tr>
</tbody>
</table>

Table 1. Crown to Implant Ratios (CIRs) of Implant Supported Prostheses (Single Crowns, Fixed Partial Denture [FPD], Cantilevered Bridges)
monitored 326 implants (Bicon) whose mean CIR was 1.6. Forty patients had a CIR > 2. They concluded that an increased CIR did not result in an increased amount of bone loss, implant failure, or crown failures, but there was an increased amount of prosthetic problems associated with an increased CIR (eg, crown loosening [21/326] and fracture of 2-mm wide posterior abutments [3/61]).

Another study specifically evaluated bone loss related to CIRs (no survival data provided). Gomez-Polo, et al27 assessed the correlation between crown-implant ratios and bone resorption in 69 patients with 85 implants. After 5.7 years, they reported that CIRs of 0.43 to 1.5 were not associated with peri-implant bone loss.

A systematic review by Blanes28 that addressed CIRs included only 2 of the above studies,18,19 because investigations did not meet their inclusion criteria (eg, monitoring for > 4 years). They concluded that CIRs do not affect peri-implant crestal bone loss. In addition, they reported that the survival rate of prostheses with a CIR of more than 2 was 94.1%. Three other studies contained data with respect to CIRs when implants were used to support short span cantilevered bridges.24-26 The reported CIRs, the percentages of implant survival after 5 years, the number of assessed implants for each study, and the mean or range of implant sizes are listed in Table 1. Elevated CIRs on abutments for cantilevered bridges associated with successful prostheses further support the concept that implant restorations can successfully tolerate CIR values that were considered risky ratios for teeth.

From a different perspective, there are still unanswered questions. For instance, Blanes28 questioned if the fulcrum point for prostheses with a large CIR is at the crown implant connection or at the most coronal bone-implant contact area. Most studies used the former for measurements, and only his investigation19 used the bone-implant contact area as the fulcrum point to calculate CIRs. Obviously, the latter results in larger CIRs (Figures 1, 2a to 2c, and 3a to 3g). The authors suggested that the bone-implant contact area was probably the
fulcrum, because components connected to the implant were stronger than the cortical bone. Another issue not resolved relates to how different prosthetic designs (eg, single crowns (Figure 1), fixed partial dentures, straight-line splinting (Figures 2a to 2c), splinting around a curve of an arch (Figures 3a to 3g) impact on the relationship between CIRs and peri-implant bone loss, technical problems and survival of prostheses.

The authors of this review paper agree with Blanes\textsuperscript{28} with respect to defining the clinical crown portion as the restored crown plus the abutment collar plus the part of the implant not encased in bone (Figures 1 to 3g). In other words, the level of the bone is considered the fulcrum for computing CIRs. This does not preclude that a potential weak point of prosthetic failure may occur at the abutment-implant interface. However, the most important fulcrum point exists at the level of the most coronal bone to implant contact. This is the location where the applied forces and strains they create are resisted by the bone.

**SHORT VERSUS LONG DENTAL IMPLANTS**

In general, finite elemental analysis studies indicated that forces on dental implants are transferred to the bone crest adjacent to implants\textsuperscript{29,30} and a small amount of stress is conveyed to the apical region.\textsuperscript{30} These data provide an important premise supporting the use of short implants. Namely, if stresses are placed at the crest after osseointegration occurred, then the length of the implant might not be the crucial factor with regard to distributing prosthetic loads to the interface between bone and the implant. Accordingly, it is important to assess the survival of short implants, which usually have increased CIRs when restored. However, there are many variables (Table 2)\textsuperscript{31} that make it difficult to compare success rates in different studies. Nevertheless, the preponderance of data indicate that short implants are very successful and that survival rates for short textured implants are comparable to longer implants.\textsuperscript{31-34}

In this regard, 4 review papers evaluated survivability of short dental implants and concluded that they could predictably be employed to support prostheses.\textsuperscript{31-34} Recently, a systematic review concluded that there was no statistically significant difference in survival rates between short (≤ 8 or ≤ 10 mm) and conventional (> 10 mm) rough surfaced implants placed in totally or partially edentulous patients.\textsuperscript{35}

<table>
<thead>
<tr>
<th>Table 2. Variables and Confounding Factors When Comparing Studies With Respect to Survivability of Short Implants\textsuperscript{31}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PATIENT:</strong> Systemic health, smoking status, periodontal status, parafuction, personal hygiene, professional maintenance</td>
</tr>
<tr>
<td><strong>IMPLANTS:</strong> Type, length, width, surface characteristics, shape, internal connection, external connection</td>
</tr>
<tr>
<td><strong>BONE TYPE:</strong> I, II, III, IV</td>
</tr>
<tr>
<td><strong>SURGERY:</strong> Skill of surgeon, bone grafting or not</td>
</tr>
<tr>
<td><strong>PROSTHESIS:</strong> Splinted or not, crown to implant ratio, fixed partial denture, cantilever</td>
</tr>
<tr>
<td><strong>SURVIVAL RATE:</strong> Size of the study, duration of monitoring period</td>
</tr>
</tbody>
</table>

Modified from Morand and Irinakis\textsuperscript{31}
Historically, studies indicated longer implants had a greater survival rate than shorter implants when a 10-mm length was used as the cut point. Renouard and Nisand documented that 11 of 12 investigations reported a higher failure rate with short implants than longer implants when machine surface implants were used. The 12th study employed machined and hydroxyapatite-coated implants. In contrast, Renouard and Nisand reported that 9 studies indicated that implant length did not affect the survival rate and 6 of the 9 investigations included in their assessment used textured surface implants.

Many older studies and 7 recent investigations published between 2006 and 2010 all indicated that short implants had a high survival rate and could predictably be used to support crowns and prostheses. Currently, textured surface implants are usually employed.

**VERTICAL CANTILEVER FORCES**

With regards to the biomechanics of increasing the crown to root or implant ratio, as a crown becomes larger, bending moments can detrimentally affect a prosthesis. To compute the magnitude of a force moment, it is necessary to multiply the force by the perpendicular distance (moment arm) from the fulcrum to the endpoint of the lever arm. Conceptually, the occlusal height of a crown should not affect the force moment along the vertical axis, because if it is centered, its effective moment arm is nonexistent. However, noncentered occlusal contacts or lateral loads are prevalent and can induce considerable moment arms, thereby torquing the prosthesis. Therefore, as the clinical crown to implant length increases, there is a greater lever arm that potentially can amplify stress on the restoration. It is evident that with a larger clinical crown and smaller implant there potentially will be a bigger lever arm. Bidez and Misch indicated that when a crown height is increased from 10 to 20 mm there is a 100% increase of force on the implant. In addition, angulation is a force magnifier and Misch and Bidez noted that a 12° angle increased the force on an implant by 20%.

Increased stress has the potential to decrease survivability of prostheses or create biological and technical problems. Fortunately, prostheses with increased CIRs from one to 2 have demonstrated a high survivability rate (Table 1). Similarly, short implants that support prostheses that usually manifest an increased CIR have demonstrated high survival rates (Table 3). The precise height that cannot be exceeded to avoid de-osseointegration or fracture of an implant is unknown and will be affected by factors such as
implant diameter, splinting of implants, and magnitude, duration, frequency, and direction of occlusal forces.

Studies have indicated that with increased CIRs there was no additional bone loss compared to locations that did not have increased CIRs.17-20,24,26 In general, there is a dearth of information that addresses how often technical complications occur around restorations with increased CIRs pertaining to various prosthetic designs: single tooth, straight-line splint, or fixed restorations that have cross arch stabilization. Of the 7 studies listed in Table 1 that discussed CIRs, only 2 reported the occurrence of technical problems.18,23 Tawil and Younan18 noted the incidence of screw loosening (7.8%) and porcelain fractures (5.2%) among teeth with increased CIRs. These data are within the 23% technical complication rate for implant supported FDPs noted in the systematic review by Berglundh, et al.67 Urdaneta, et al23 reported 3 fractures (3/61) of the 2-mm wide abutments used in the posterior areas when the CIR was 1.47 and no fractures among 3-mm wide abutments (184/184) when there was an increased CIR. They also noted that 21 of 326 crowns loosened during the observation period and 90% of the time this occurred in the maxillary anterior region. It was suggested that splinting of multiple adjacent implants might have avoided these undesirable sequelae.

Several studies that assessed the utility of horizontal cantilevers also recorded increased CIRs (Table 1).24-26 These investigations usually reported minor technical problems associated with short span cantilevered bridges that had increased CIRs (see Aglietta, et al68 for review). While both vertical and horizontal cantilevers may increase stress on implants and the prosthesis that they support, the resultant problems may not be exactly similar. For instance, a prosthesis with an increased CIR due to a vertical cantilever may be supported on both ends with a terminal abutment and this may alter the types of technical problems that may occur.

Other investigations that assessed the survival of short implants did not address technical problems that may occur if an increased CIR was created upon prosthesis fabrication.32-35 At present, no definitive

### Table 3. Studies Dedicated to Assessing Survival Rates of Short Dental Implants

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>No. of implants</th>
<th>Length</th>
<th>Type</th>
<th>Surface</th>
<th>Survival Rate</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anitua, et al66</td>
<td>293</td>
<td>532</td>
<td>7 to 8.5 mm</td>
<td>BTI</td>
<td>rough</td>
<td>99.2%</td>
<td>31 months</td>
</tr>
<tr>
<td>Arlin, et al59</td>
<td>not reported</td>
<td>35</td>
<td>6 mm</td>
<td>ITI</td>
<td>rough</td>
<td>94.3%</td>
<td>2 years</td>
</tr>
<tr>
<td>Fugazzotto33</td>
<td>1,774</td>
<td>2,073</td>
<td>6 to 9 mm</td>
<td>ITI</td>
<td>rough</td>
<td>98.4%</td>
<td>36.2 months</td>
</tr>
<tr>
<td>Goene, et al61</td>
<td>188</td>
<td>311</td>
<td>7 to 8.5</td>
<td>Osteotite</td>
<td>acid etched</td>
<td>95.8%</td>
<td>3 years</td>
</tr>
<tr>
<td>Grant, et al57</td>
<td>124</td>
<td>355</td>
<td>8 mm</td>
<td>Nobel</td>
<td>not reported</td>
<td>99%</td>
<td>&lt; 1 to ≥2 years</td>
</tr>
<tr>
<td>Griffin, et al58</td>
<td>167</td>
<td>168</td>
<td>8 mm</td>
<td>SO, Nobel</td>
<td>HA coated</td>
<td>100%</td>
<td>34.9 months</td>
</tr>
<tr>
<td>Malo, et al59</td>
<td>237</td>
<td>408</td>
<td>7 and 8.5 mm</td>
<td>Nobel</td>
<td>machined/TiUnite</td>
<td>96 to 97%</td>
<td>5 years</td>
</tr>
<tr>
<td>Misch, et al60</td>
<td>273</td>
<td>715</td>
<td>9 mm</td>
<td>BTI</td>
<td>rough</td>
<td>99.2%</td>
<td>12 to 60 months</td>
</tr>
<tr>
<td>Nedir, et al21</td>
<td>236</td>
<td>264</td>
<td>6 to 9 mm</td>
<td>ITI</td>
<td>TPS SLA</td>
<td>100%</td>
<td>7 years</td>
</tr>
<tr>
<td>Tawil, Younan18</td>
<td>111</td>
<td>269</td>
<td>7 to &lt; 10 mm</td>
<td>Nobel</td>
<td>machined</td>
<td>95.5%</td>
<td>12 to 92 months</td>
</tr>
<tr>
<td>Testori et al52</td>
<td>not reported</td>
<td>31</td>
<td>7 to 8.5 mm</td>
<td>Osteotite</td>
<td>acid-etched</td>
<td>96.7%</td>
<td>4 years</td>
</tr>
<tr>
<td>van Steenberge, et al62</td>
<td>-</td>
<td>10</td>
<td>8 mm</td>
<td>Astra</td>
<td>rough</td>
<td>100%</td>
<td>2 years</td>
</tr>
<tr>
<td>ten Bruggenkate, et al63</td>
<td>126</td>
<td>253</td>
<td>6 mm</td>
<td>ITI</td>
<td>TPS</td>
<td>97%</td>
<td>1 to 7 years</td>
</tr>
</tbody>
</table>

*Studies listed alphabetically.*
CONCLUSIONS

The available data (Table 1) demonstrate that prostheses with increased CIRs up to 2 have a high survival rate. Furthermore, increased CIRs did not result in additional peri-implant bone loss. Therefore, when there is a dearth of bone or anatomic structures that preclude placement of longer implants, treatment planning a prosthesis that results in an increased CIR is a reasonable, predictable procedure. Furthermore, since placement of short implants often results in increased CIRs, the clinical implication is that short implants (< 10 mm) can be used to support a prosthesis and do not result in early demise of a restoration. Ultimately, when necessary, utilization of short implants and prostheses with increased CIRs provide greater flexibility when treatment planning patients.

These conclusions are in agreement with recent statements by the European Association for Osseointegration, which indicated the following:

- Consensus statement: “Restorations with a CIR up to 2 do not induce peri-implant bone loss.”
- Clinical implications: “A FDP or single-tooth restoration with a CIR up to 2 is an acceptable prosthetic option.”

Nevertheless, it is recognized that a prosthesis with an increased CIR is subject to increased occlusal forces. This can result in amplified stress on the prosthesis and the surrounding bone. Accordingly, it is advantageous to reduce forces on restorations with an increased CIR. Ten suggestions are listed in Table 4 for how to diminish stresses on prostheses with an increased CIR, thereby possibly reducing biological and technical complications and increasing the survivability of these constructs.

### Table 4. Clinical Suggestions for Restoring Teeth With Increased Crown to Implant Ratios

<p>| | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>In posterior areas, restore the occlusal surfaces of teeth in such a manner that the patient’s incisal or canine guidance discludes the posterior teeth and minimizes lateral contact in mandibular excursions.</td>
</tr>
<tr>
<td>2.</td>
<td>Increase the number of implants supporting the prosthesis. This adds to the surface area where occlusal forces are transmitted.</td>
</tr>
<tr>
<td>3.</td>
<td>Increase the bone implant contact area with wider implants.</td>
</tr>
<tr>
<td>4.</td>
<td>Reduce the occlusal width of posterior teeth and have centric contacts centered over the implants.</td>
</tr>
<tr>
<td>5.</td>
<td>Avoid elevated CIR in bruxers or over engineer the case with additional implants and splint around the turn of the arch with the restoration when possible.</td>
</tr>
<tr>
<td>6.</td>
<td>Patients can wear a night guard to reduce nocturnal stresses on the prosthesis.</td>
</tr>
<tr>
<td>7.</td>
<td>Short implants should be splinted together to maximize their support of the prosthesis and provide cross arch stabilization when possible.</td>
</tr>
<tr>
<td>8.</td>
<td>Use textured-surfaced implants that have a higher percentage of bone implant contact.</td>
</tr>
<tr>
<td>9.</td>
<td>Flatten cuspal inclines.</td>
</tr>
<tr>
<td>10.</td>
<td>Employ implants with decreased thread pitch (distance between the threads), thereby resulting in an increased number of threads per unit length and an increased surface area. However, there are no data that the thread pitch altered the survival rate of prostheses with increased CIRs.</td>
</tr>
</tbody>
</table>

\[\frac{3}{\text{REFERENCES}}\]

39. Jemt T. Failures and complications in 391 consecutively...
Importance of Crown to Root and Crown to Implant Ratios


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POST EXAMINATION QUESTIONS

1. Factors which influence the number of abutments to support a fixed dental prosthesis (FDP) include which of the following?
   a. Number of missing teeth.
   b. Anticipated occlusal forces.
   c. Amount of available bone around abutments.
   d. All of the above.

2. With respect to teeth, the following procedures reduce the CRRs:
   a. A low profile overdenture abutment.
   b. Tooth extrusion.
   c. Both A and B.
   d. Occlusal onlays.

3. Strategies to consider when fabricating fixed dental prostheses with increased CIRs include the following:
   a. Minimize lateral excursions on posterior prostheses and increase the number of supporting implants.
   b. Increase clinical crown height.
   c. Employ textured surfaced implants.
   d. Both A and C.

4. In this review paper, the authors define the clinical crown as:
   a. The sum of the restored crown plus the abutment collar plus the portion of the implant coronal to the bone.
   b. The height of the titanium abutment minus 2 mm for biologic width space.
   c. The sum of the interarch space plus the height of the restored crown plus the height of the abutment.
   d. The height of the restored crown.

5. In the study of increased CIRs by Rossi, et al the assessed implants were:
   a. The 6-mm long implants.
   b. The 4.1-mm diameter implants and the 4.8-mm diameter implants.
   c. Splinted implants.
   d. Both A and B.

6. To calculate the bending moment, it is necessary to multiply the force by what?
   a. The perpendicular distance (moment arm) from the fulcrum to the endpoint of the lever arm.
   b. The perpendicular distance (moment arm) from the fulcrum to the apex of the tooth.
   c. The perpendicular distance (moment arm) from the fulcrum to the cemento-enamel junction.
   d. The perpendicular distance (moment arm) from the fulcrum to closest tooth.
7. In the study pertaining to increased CIRs by Blanes, et al the assessed implants had which features?
   a. Monitored for 2.5 years.
   b. Restored with CIRs of 6 or more.
   c. Smooth surfaced implants.
   d. None of the above.

8. In this review paper, the authors define the location of the fulcrum between the clinical crown and the implant as:
   a. Occurring at the junction of the restoration and the implant abutment.
   b. Occurring at the level of the first bone to implant contact.
   c. Occurring at the implant-abutment interface.
   d. Occurring within the body of the implant half way from the osseous crest to the apex of the implant.

9. Factors which will affect an implant’s ability to resist biologic and technical complications include:
   a. Increasing implant diameter.
   b. Use of porcelain fused to metal crowns.
   c. Splinting of implants, particularly across the turn of the arch.
   d. Both A and C.

10. Which procedures increase the CRR with respect to teeth?
    a. Increasing vertical dimension.
    b. Surgical crown lengthening.
    c. Both A and B.
    d. Ridge augmentation.

11. Urdaneta, et al demonstrated that an increased CIR resulted in what effect on bone around the dental implants?
    a. Additional bone loss.
    b. No additional bone loss.
    c. Bone apposition.
    d. Increased osseous density of bone.

12. The preponderance of data in Table 3 indicate that short implants demonstrate which characteristic?
    a. Are very successful and that survival rates for short textured implants are comparable to longer implants.
    b. Are very successful and that survival rates for short smooth surfaced implants are comparable to longer implants.
    c. Are not very successful and that survival rates for short textured implants are not comparable to longer implants.
    d. Are not very successful.

13. According to Bidez and Misch, when a crown height is increased from 10 to 20 mm, the increase of force on an implant is how large?
    a. 25%.
    b. 50%.
    c. 75%.
    d. 100%.

14. The European Association for Osseointegration reached which of the following conclusions?
    a. Restorations with a CIR up to 2 do not induce peri-implant bone loss.
    b. FDP or single-tooth restoration with a CIR up to 2 is an acceptable prosthetic option.
    c. Both A and B.
    d. Restorations with a CIR up to 1 do not induce peri-implant bone loss.

15. Techniques to reduce forces on restorations with an increased CIR include which of the following?
    a. Restore the posterior occlusal surfaces of teeth so canine guidance discludes the posterior teeth and minimizes lateral contact in mandibular excursions.
    b. Increase the number of implants supporting the prosthesis.
    c. Increase the bone implant contact area with wider implants.
    d. All of the above.

16. What is the precise crown to implant ratio that cannot be exceeded to avoid deosseointegration or fracture of an implant?
    a. Unknown.
    b. 1.
    c. 1.5.
    d. 2.
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Please check the correct box for each question below.

1. ☐ a ☐ b ☐ c ☐ d  9. ☐ a ☐ b ☐ c ☐ d
2. ☐ a ☐ b ☐ c ☐ d  10. ☐ a ☐ b ☐ c ☐ d
3. ☐ a ☐ b ☐ c ☐ d  11. ☐ a ☐ b ☐ c ☐ d
4. ☐ a ☐ b ☐ c ☐ d  12. ☐ a ☐ b ☐ c ☐ d
5. ☐ a ☐ b ☐ c ☐ d  13. ☐ a ☐ b ☐ c ☐ d
6. ☐ a ☐ b ☐ c ☐ d  14. ☐ a ☐ b ☐ c ☐ d
7. ☐ a ☐ b ☐ c ☐ d  15. ☐ a ☐ b ☐ c ☐ d
8. ☐ a ☐ b ☐ c ☐ d  16. ☐ a ☐ b ☐ c ☐ d

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