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Review Article

Effects of Implant/Crown Ratio on Crestal Bone Loss: A Review

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Abstract

With the use of an implant in dentistry, new treatment planning has emerged as an alternative to traditional treatment methods in many cases, from single missing tooth to complete edentulous archs. Besides this, the use of short implants has become popular due to the inadequate amount and quality of bone in some cases and the position of anatomical formations that are not allowing the implant placement to the desired length. There are studies that claims the use of short length implants showed high success rates with the provision of osseointegration. On the other hand, there are also researchers who think that the use of short implants will have a negative impact on success due to the use of restorations with a high crown to implant ratio. It is thought that the crown to implant ratio differs from the crown to root ratio of natural tooth because of the absence of the periodontal ligament of the implant and the attachment to the bone via osseointegration. For this reason it is not possible to say a constant and clear ideal crown to implant ratio. There are studies that attempt to determine the safe range of this ratio by examining the relationship between the ratio of crown to implant and implant failure, marginal bone loss, survival rate and connection design.

Keywords: Crown to Implant Ratio; Implant Survival Rate; Crown Heigth Space; Marginal Bone Loss; Connection Design

Introduction

Treatment of tooth loss with implant supported restorations has become an indespensable option in recent period. Because of protection of the natural teeth and existing bone is the reason why the implant supported rehabilitation is the better choice.

Any number of studies have demonstrated the effectiveness of dental implants for rehabilitation of missing teeth in the posterior region [1-4]. Using the short length implants has recently become popular because of the height of the alveolar bone is not always appropriate. Thanks to usage of short implants, there is no need for bone augmentation and additional surgical treatments. In this manner, it is possible to obtain financial benefits and time saving. A lot of publications handle the length of the implant as a major factor for the implant survival [5-16]. While some studies report higher failure rates [5-9], others advocate high survival rates [10-16]. A recent study has shown that short implants have been failed before than the standard implants, although they have approximately similar survival rates [5].

Although implant supported restorations are used so often, there is no guideline that contains specific rules for the application of implants. So it is inevitable that many of the rules applied to the natural tooth will also be applied to implant-assisted restorations. Crown to root ratio that is major result of the usage of short length implants is one of these guidelines that is applying according to the natural tooth. Crown to implant ratio can be defined in two different ways as anatomical and clinical ratio. While clinical crown to implant ratio is determined by radiograph [17] and it is the ratio of the coronal part of the tooth above the alveolar bone level to the apical part of he tooth below the alveolar bone level, in the anatomical ratio, the fulcrum of the lever arm is located at the implant shoulder. The crown to implant ratio is the correlation of restoration length and implant length which resides in the bone. Under the terms of this situations, the length of the implants is the measured from the apex to the most coronal bone-implant contact and the crown length is the measurement between the top of the restoration and the most coronal bone contact [18]. This ratio frequently used for determining a teeth is used for an abutment as a removable or fixed prothesis. Moreover, one of the most important factor contributing to the long term prognosis of the tooth is the rate of the crown and root [19-21]. While evaluating the ratio of crown to implant, it is more factual to take clinical ratio [22].

According to the long accepted view, ideal crown to root ratio is 1:2 or smaller for the natural tooth [19-21]. Newmann., *et al.* and Mcguire and Nunn have reinforced this by doing studies that examine the rate of crown and root [23,24]. However, opposing to the Ante's law, it is shown that the fixed dental protheses with an unfavourable crown ratio can be maintained in a successfull manner [25-27]. Nevertheless, there is no ideal ratio for crown to implant [19-21]. Misch argues that, crown to implant ratio needs to be considered differently from the crown to root ratio [28]. Also emphasizes that an implant does not rotate within the bone, that implant length is not an issue of mobility, and does not affect endurance to lateral forces. The attachment of the natural teeth and the attach-

ment of the implant to the bone are in different ways. While the natural teeth are held together with the periodontal ligament of the bone, the implant that is osteointegrated acts as an anchored tooth. The periodontal ligament, whose primary function is to hold a tooth in the alveolar socket, provides a wider physiological mobility to the natural teeth than osteointegrated dental implant [29]. When a force of 0.1N is executed to a tooth that has an healthy periodantal ligament, its mobility is between 50 and 200 micron. Although the same force perform on an implant, its mobility is only 10 micron [30,31]. The high rigidity of a dental implant leads to transmission of great force that may cause resorption to the alveolar bone [32].

An implant supported prothesis is a kind of a type 1 lever that means any increase in crown height comes to conclusion increasing the force moment which is supplied by the implant and bone that surrounds the implant [33,34]. Besides this, an unfavourible crown to implant ratio has been accepted as a non-axial loading [35,36]. The longer the length of the crown is, the longer the lever arm becomes and the stress in the bones increases which in turn creates an environment for the formation of bone resorption. According to the Toronto Consensus Report in 1998, 1,5 mm bone loss in the first year and 0,2 mm bone loss for annually after first year is acceptable [37]. Rangert and colleagues found a positive correlation between high crown to implant ratio and increased alveolar bone resorption [35]. However there is a confliction about the results of crown to implant ratio or the threshold value of this ratio. Furthermore, Nissan., et al. defend that the crown high space that is the distance between the occlusal plane and the crestal bone has a more detrimental effect on bone resorption and prosthetic complication than the effect of the crown to implant ratio [38,39]. If crown heigth space increases 1mm, the cervical load increases by 20% [40].

Unfortunately, there is a little knowledge about the effect of the crown to implant ratio on the implant survival. Naert., *et al*. shown that long abutments used in the branemark system are associated with bone destruction in a short period, although this difference disappeared over time [41]. Also, Rokni., et al. considered the effect of the crown to implant ratio on the periimplant crestal bone levels. They found the mean crown to implant ratio 1,5 and observed that this ratio did not affect the marginal bone loss around the dental implants [11]. Rafael juan blanes., *et al.* evaluated ITI implants that places molar and premolar region. According to the results, crown to implant ratio and crestal bone loss are in inverse relationship. They found that crown to implant ratio between 2 and 3 may be safely used in the posterior region [42]. This inconsistecy may be explained by several factors. Firstly, when the occlusal force is considered variable it is quite difficult to measure its direction and size correctly [43]. Another factor is, there is no threshold value for resorption or remodeling associated with bone stress [44]. Finally, the genetic influence may affect the load bearing capacity of the bone [45].

There is a lot of studies about crown to implant ratio with different results. The purpose of this compilation surveying these workings, comparing the results, determining the circumtances and enlighten the researchers who may have a new point of view about crown to implant ratio.

Crown to implant ratio: Implant failure

Implant survival depends on many factors that are originated from technical, biomechanic agents as well as patient and clinician associated factors. The crown to implant ratio is also one of the factors addressed in this regard. Much work has been done in this argument which has a mean ratio between 0,82/1 and 2,44/1. All of these studies have found no correlation between crown to implant ratio and implant survival rate [11,15,29,34,37,42,46-54]. Most of the researches about survival rate concerns on short implants. Anitu., *et al*. evaluated short dental implants on 293 patients with 532 implants for 5 years retrospectively. They found 98.7% survival rate and approved using short implants in posterior areas [29]. Besides this, Gentile., *et al.* compares short Bicon dental implants (5.7 mm) with bicon implants greater than 8mm. According to the results no difference found in survival rate [16]. Because many factors are attributed to the loss of implants, the crown to implant ratio is not the one and only cause for the failure.

Crown to implant ratio: Marginal bone loss

Marginal bone loss is one of the expected outcomes for prosthetics with a high crown to implant rate. Although there have been many studies on this controversial issue, no clear result has yet emerged. There are researchs showing increased bone loss as the crown to implant ratio increases [54], as well as studies showing a decrease [42,50], or not finding a ratio [11,12,29,34,37,46,49,51,53].

Rokni., *et al.* evaluated crown to implant ratio and maginal bone loss that found no correlation between them. Also they revealed that long implants had much more crestal bone loss than short implants [11]. Blanes., *et al.* found inverse relation between marginal bone loss and crown to implant ratio. They admitted crown to implant ratio between 2 and 3 can be used safely. These two researches [15,42] showed similar results about the bone levels in the follow up period. However, one of the two studies couldn't find positive or negative correlation between the crown to implant ratio and peri-implant crestal bone level [15], whereas the other found statistically significant results about bone loss and high crown to implant ratio [42]. Unlike these, in the study Gomez deals with, in 2 years, crown to implant ratio increased from 1,5 to 1,8 because of bone resorption and crown to implant ratio between 0,43 and 1,5 were not associated with periimplant bone loss [47]. Lee., et al. handle the same issue and found inverse relation. They also found that, maxilla and mandibula are affected differently from the crown to implant ratio [50]. According to them maxilla

had greater bone loss. Malchiodi., *et al*. determined the safe space when the crown to implant ratio between 3.10/1 and 3,40/1 [52].

Blanes was giving point to distinctive prosthetic treatment approaches on bone loss such as splinting and cantilever extension. The use of cantielever extensions has been suggested for fourty years [42]. Several authors thought that more stress accumulates in the part of the prosthesis close to the cantilevered end [42]. White., *et al.* and Tashkandi., *et al.* showed this cantilever induced crestal bone stresses on in vitro studies [55]. However, long-term clinical trials have shown that the results observed in vitro are inconsistent with clinical practice [56,57]. Blanes's results also reinforces these clinical studies and they recommend that the use of one tooth cantilever extensions either mesial or distal component of the implant restoration, does not affect the marginal bone loss around the implant. Usage of the one tooth cantilever extensions may be an alternative as a treatment options.

Because of reducing load risk factors, in the prosthetic treatment splinting multiple dental implants is recommended [35]. In contrast to splinting, using the single units ensure more satisfying prosthetic approach such as improved passive fit, better oral hygiene and easy access to teeth in emergency circumstances [51]. Blanes., *et al.* evaluated splinting multiple implants on crestal bone loss and they found no correlation between them.

Crown to implant ratio: Technical complications

Some of the authors handled the effect of crown to implant ratio on technical complications besides marginal bone loss. Tawil., et al. observed that 7.8% screw loosening, 5.2% porcelain fracture and 0.3% implant fracture when crown to implant ratio between 1 and 2. According to the statictics, there isn't any correlation between crown to implant ratio and technical complications [15].

Schneider., *et al.* studied the relation between complications and crown to implant ratio. No statistically remarkable effect of the crown to implant ratio was found on the implant survival, marginal bone loss and complication occurance rate. When adjusted for the crown to implant ratio, smoking was the only co-factor importantly associated with implant failure and biological complications [51].

Crown to implant ratio: Crown height space

The crown height space is measured from occlusal plane to the crestal bone. Nissan and collaegues, in more than one studies, advocated that the crown height space has more significant effect than the crown-to-implant ratio in evaluation of the biomechanics-related detrimental effects on prosthetic complications [38,39]. Nissan., *et al.* determined the threshold of the crown height space is 15mm. Biomechanically, crown height space greater than 15 mm is considered as unfavourable.

Anitu., *et al*. found found that, while the crown height space of about 17 mm, bone loss occurs less than 2 mm, when the crown height space average of about 21 mm, the bone loss is greater than 2 mm. According to Anitu., *et al.* Crown height space is more effective parameter than crown to implant ratio on occurance of the bone loss [29].

Crown to implant ratio: Implant surface design

Useage of short implants appears to be a good alternative to in resorbed bones. However in the past, short implants have been related with low success rates [12]. Furthermore, new researches show that short implants can achieve clinical success at the same level when compared to longer implants [8,49,58]. Moreover, in many cases, the theoretical analysis demonstrated that 2 to 3 mm of the coronal portion of the implant bears the main load transfer to the bone. These results can be understood as a reason for choosing short implants if they are well stabilized in the residual bone. When all this is thought, it is considered that with the optimized implant design and surgery protocol, short length implants can play a more significant role in severely resorbed maxillary rehabilitation.

Frank., *et al.* studied for determining the survival rates of the machine implants and oxidized implants [12]. In this comparisation, the results are not statistically different and the survival rate was 94,6%.While the other analysis pointed to lower results than the oxidative implants for the machined implants, there is no statistically significant difference. Experimental study and clinical histology showed a greater bone response to oxidized implants than machined implants [59]. The results of these and other studies show that surface alterations may be important in challenging situations [60-623]. In some studies that are reporting high survival rates, implants used had a rough surface design [8,49,58].

Crown to implant ratio: Connection design

Inconvenient design and insufficient planning may be relevant to the failure of dental implants. One of the main reasons for the implant overloading is inadequate integration of supporting structures of prothesis [63-68]. Finally, proper seal and passive fit between the implant and its upper structures are the factors that determine the success rate and survival. The other case that frequently occurs in edentulous areas is increased interocclusal space due to bone resorption that requires usage of long length crowns which lead to inappropriate crown to implant ratio. Crown heigth space is measurement bewteen the crestal bone and proposed incisal edge position. In fixed prothesis, crown height space sould be between 8 and 12 mm [67,68]. Implant and abutment conncections, such as the height of the crown, is also one of the important issue addressed in terms of fracture resistance. When an implant fracture happens, fixing up of the implant is very difficult because

of the complications. If all causes of fracture are considered, they can be treated in three groups such as; failure of the implant design, an absence of passive adaption of the crown and overload because of parafunctional habits. Sergio evaluated implant and abutment connections on the fracture resistance and they found resistance to the nonaxial forces are seiously affected by the connection design of the implant and abutment [69]. According to the Sergio, when the crown height length is 8mm, the fracture strength is greater than the average maximum bite force which is 596 N for women and 789 N for men [64]. According to Sergio, morse taper implants indicated the lowest loss in strength than the other groups that were internal hexagon and external hexagon [69]. When the interocclusal space are high and requires long lentgh of the crowns, the implant abutment connections gain importance for performance and resistance of the system [69]. In a study involving platform switched restored implants and conventionally restored implants, there is no statistically different on the survival rates. However, it is found that marginal bone loss around the platform switched restored implants is lower than the conventionally restored implants.

Crown to implant ratio: Crown height space

It has been thought that occlusal overloading is thought to be the primary cause of impairment of the integrity of peri-implant tissues and early implant failure [70]. In a research that was performed Chambrone and colleagues, they could not show whether the excessive occlusal loading had an adverse effect on osseointegration [71]. Possible explanations were lack of knowledge about prosthetic factors.

There are lots of researches that examine the influences of smoking on implant success. Among the factors affecting the patient, Schneider., *et al*. found that smoking associated with increased biological crown to implant ratio was strongly related with implant failure and much more biological complications [51]. In a lot surveys, it as mentioned about the low implant survival rate and insufficient peri-implant mucosal health because of the negative effect of the smoking [72-74].

The antagonist arch in short implant use is also an important criterion for implant health and bone loss occurance. According to the study of Anitu., *et al.* the antagonist type has a strong effect on the crestal bone loss around extra short implants [29]. Those with fixed implant-supported prostheses as antagonist arches have more bone loss than full prostheses or natural teeth.

Discussion

Bone loss after tooth extraction causes an unfavorable bone quantity for implant placement [75]. To overcome the problem of bone loss, bone augmentation procedures are generally suggested to form a better circumtances for implant osseointegration. However, this may lead to some complications such as bleeding, infection and morbidity of donor site. These processes are quite costly and time consuming at the same time. Usage of short implants has come question to avoid all these risks when bone levels have not been sufficient [76-79]. The use of long implants has been defended for years to lessen the amount of bone stress in the crestal bone. However, with the advancement of implant technology and consequently changes in implant surfaces, the size of implants should have been started to be questioned. In subsequent publications, it has been supported that short implants and long implants have similar survival rates in terms of success and longevity [8,14]. In spite of a general opinion that longer implants have improved biomechanical prognosis of restoration, this assumption is in conflict with some studies which suggest that a significantly larger diameter has strong effect for improved implant anchorage [80]. Pierrisnard., *et al.* have advocated that the use of short length implants may even be useful for the biomechanical prognosis [81]. Through the finite element analysis, the researchers indicate that if the length of the implant increases, the stress also increases around the implant. In addition, it has been shown that when short implants experienced the nonaxial forces, they tend to move in the bone, whereas longer implants have a tendency to curl when exposed to the same stress. By the way, with the use of shorter implants, some researchers advocated that the restoration with higher crown to implant ratio, leading a great risk for crestal bone loss [35]. In a study, this risk was found more related to the length of the crown, compared to the length of the implant. In this study less bone resorption occurs when the ratio of crown to implant was reduced by decreasing the length of the crown more than by increasing the length of the implant [82].

In a sixty months follow-up study, Brose., *et al.* found that single implant supported restorations that have disproportinate crown to implant ratio have strong effect on the implant failure rate than crestal bone levels or pocket depths [83]. On the contrary, there are also researchers who argue against the later studies. Blanes., *et al.* suggestsed that implant-supported prostheses with higher crown to implant ratios lead to less marginal bone loss than others that have lower crown to implant ratio [42].

There is no accepted rate for the ratio of crown to implant in spite of the ideal rate of crown to root is assumed to be 1: 2 or less. Penny and Kraal had the result that a crown-implant ratio of 1: 2 was very conservative and could restrict treatment [84]. Shilinburg argues that the 1: 1.5 relationship is more accurate and that the 1: 1 relationship is the absolute minimum accepted under favorable conditions [85]. According to a consensus group of the European Academy of Osseointegration crown to implant ratio was accepted 2:1 [29]. However there are clinical trials showing that implants with a much higher rate of crown to implant are highly successful. For this reason it is not right to say a definite rate for the rate of crown to implant because they have different attachment mechanism to the bone.

The high rate of crown to implant and its effect on the bone loss and implant survival rate is a very controversial issue. Some researchers could not find any correlation between the rate of crown to implant and marginal bone loss [11,15,29,34,47,49,51,53]. These results can be clarified by the interactive nature of bone stress. Masticatory forces that increased the stress intensity on the crestal bone resulted in stimulation of bone formation around some fixtures. This biological response is encouraged by the stress shielding effect that means that implants placed in the bone reduce the stress of the bone by reducing the density of the bone in that region [86]. In view of these authors when bone stress is diminish, it causes atrophy and crestal bone loss finally. Besides this, there are also studies that show results with inverse relationships. Blanes., *et al*. and lee., *et al.* advocated that higher crown to implant ratio associated with less crestal bone loss [42,50]. Wennstrom., *et al.* found that in their retrospective study, increasing crown to implant ratio were directly proportional to increased bone destruction [54].

While Blanes., et al. found the safe space of crown to implant ratio between 2 and 3, Malchiodi., *et al.* found it between 3.10 and 3.40 [42,52]. Anitu., *et al.* suggested that the main effect on the marginal bone loss was crown height space. The greater the crown height space results in great bone loss according to the study of Anitu [29].

Conclusions

There are limited and conflicting studies about the crown to implant ratio on literature. It is not possible to say a precise rate for crown to implant by looking at studies done up to now or to determine the precise rate causes the marginal bone loss. It is not right to blame only the crown to implant ratio for implant success or marginal bone loss because many factors are responsible for implant survival or bone loss occurance. More randomize controlled studies that requires long term follow, more sample size and better calibration needs to be done in this regard for more confidental results.

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