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Evaluation of the Selected Root-to-Crown Ratio of Crowned Teeth in a Hospital Setting: A Cross-sectional Study

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AK, AKL, NFL, JL and YML conducted the investigation, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Author JA designed the study, supervised the project and revised the manuscript. All authors read and approved the manuscript.

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ABSTRACT

Aims: The root-to-crown (R/C) ratio is envisaged to influence the longevity of crowned teeth. The purpose of this study is to measure the selected R/C ratio of crowned teeth at the Royal Dental Hospital of Melbourne, and to evaluate the effect of tooth category and location on the R/C ratio.
Study Design: Retrospective study.
Place and Duration of Study: Melbourne Dental School and the Royal Dental Hospital of Melbourne, between February 2014 and July 2015.
Methodology: Peri-apical radiographs of patients treated with single tooth crowns were retrieved. The radiographs were confirmed to be of diagnostic quality and covered the entire crowned tooth. All the selected radiographs were scanned and converted to digital radiographs. With the aid of image manipulation software, the crown and root lengths were measured along the long axis of the

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tooth. The bone crest level separated the crown and the root. Subsequently, the R/C ratio was established. In addition, the mean R/C ratio was calculated for all the teeth and for every single tooth category. The impact of tooth type and location within the arch on the R/C ratio was statistically evaluated.

Results: A total of 257 crowned teeth were included. The mean R/C ratio was 1.43. Canines had the lowest R/C ratio followed by molars, incisors and premolars respectively. The significant difference existed between incisors and premolars (P = .04), and between premolars and molars (P = .01). In general, the maxillary anterior region exhibited a greater R/C ratio than the mandibular anterior region. However, for the posterior region, the mandibular teeth had a slightly greater R/C ratio than the maxillary teeth.

Conclusion: The implemented R/C ratio of the crowned teeth in this study was close to the recommended ratio of 1.5. Although differences exist between the different tooth categories, the actual difference is minimal. Thus it is difficult to set the R/C ratio recommendation for each tooth category.

Keywords: Crown; root; ratio; restoration; bone; support.

1. INTRODUCTION

Whenever a crown restoration is indicated, the clinician should ensure an optimal condition of the tooth to enhance its long-term prognosis. One of the features that are considered to have an impact on the longevity of a crowned tooth is root-to-crown (R/C) ratio [1,2]. R/C ratio is defined as the physical relationship between the portion of the tooth within alveolar bone compared to the portion outside the alveolar bone [3]. R/C ratio reflects the alveolar bone support that exists around the tooth. As a result, R/C ratio has been considered as a useful diagnostic and treatment planning tool, and it is assumed that favourable R/C ratios correlate with a favourable prognosis [1,4].

Whenever possible, a maximal R/C ratio is desirable. Anecdotally, a ratio of 2 is thought to be ideal and 1.5 is acceptable, while a ratio of 1 is considered the minimal acceptable ratio [1,2,5,6]. Teeth may suffer from R/C ratio reduction after periodontal disease, root resorption, apical surgery or lengthened clinical crown. The concern with reduced R/C ratio lies in the apical movement of the point of rotation. As a result, the effector arm, represented by the clinical crown, is increased and the resistance arm, represented by the supporting root, is reduced. Subsequently, excessive stresses will be transferred to the alveolar bone during functional movements leading to further bone loss and mobility [7,8]. However, there is currently little clinical evidence supporting R/C ratio guidelines that should be implemented by clinicians when restoring teeth with crowns. In addition, the literature does not suggest different R/C ratios for the different tooth categories. As a result, it is not clear if clinicians are considering the R/C ratio when restoring teeth with crowns. Therefore, the aim of this cross-sectional study is to measure the R/C ratio of crowned teeth for patients treated at the Royal Dental Hospital of Melbourne, which will provide an indication about the selected R/C ratio when the tooth is restored by a crown. In addition, this study evaluates the effect of tooth category and arch location on the R/C ratio. The hypothesis is that the tooth category and arch location do not have influence on the selected R/C ratio.

2. MATERIALS AND METHODS

Peri-apical radiographs of patients treated with single tooth crowns at the Royal Dental Hospital of Melbourne were randomly selected from the patients' database. The inclusion criteria were that the patients were at least 20 years of age, and receiving a post-operative peri-apical radiograph. Relevant treatment item codes were used to identify suitable patients. After obtaining the physical file of the patients, the radiographs were retrieved and evaluated for suitability. A radiograph was deemed suitable if it showed at least one entire single crowned tooth (crown and root) without distortion. Radiographs with distortion, root abnormalities or poorly formed apices were excluded.

2.1 Tooth Length Measurements

Each physical radiograph was scanned using an Epson Perfection V700 photo scanner (Seiko Epson Corporation, Nagano, Japan) to convert it to a digital radiograph. This allowed visualisation, magnification and subsequent measurement on a computer screen. Each scanned radiograph was labelled according to the tooth number. In order to measure the tooth dimensions, the digital radiograph was imported into an image manipulation software (GIMP 2.8.10, GIMP Development Team, California, USA). Subsequently, the crown length and the root length were measured by a single operator to standardize measurement for all the teeth.

In this investigation, the clinical crown and root lengths were measured (Fig. 1). The length measurements were undertaken along the tooth central long axis. For a single-rooted tooth, the tooth length was measured along the central long axis of the tooth from the apex of the root to the middle of incisal edge (incisors) or the cusp tip (canines and premolars) [9,10] (Fig. 1A). For a multi-rooted tooth, two horizontal lines were drawn by the software [10]: (1) coronal line connecting the cusp tips and (2) apical line connecting the root apices. For the maxillary molars, the palatal root was excluded due to the likelihood of deviating from the long axis of the tooth [9]. The mid-points of the two lines were connected by a vertical line on which the tooth length was measured (Fig. 1B). In order to segment the crown length and the root length from the total tooth length, a line was drawn to connect the bone crests on either sides of the tooth. Therefore, the vertical line coronal to the bone crests represents the crown length and the vertical line apical to the bone crests represents the root length. The digital images were magnified on the computer screen to facilitate the measurements. Subsequently, the generated crown and root length measurements were related to quantify the R/C ratio of the crowned teeth according to the following equation:

R/C ratio =Root Length/Crown Length

2.2 Statistical Analysis

The average R/C ratio of all the teeth was calculated. In addition, the mean R/C ratio value was measured for each tooth category of each arch. Shapiro-Wilks statistical test was performed

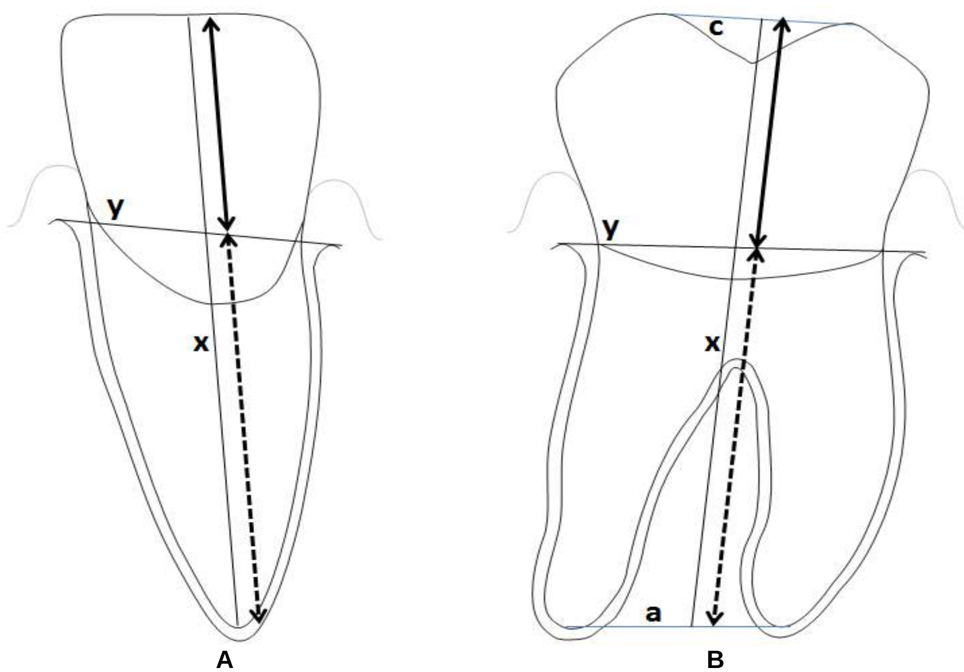

Fig. 1. The method of measuring the crown and root length. (A) For single-rooted tooth, the tooth long axis is determined (x). The line connecting the mesial and distal bone crest (y) separates the measured crown from the measured root. (B) For multi-rooted tooth, a coronal horizontal line (c) is drawn to connect the cusp tips, and an apical horizontal line (a) is drawn to connect the root apices. The long axis (x) of the tooth is established by connecting the middle points of the two horizontal lines. As per the single-rooted teeth, the bone crest line (y) separates the measured crown and root. The solid line represents the clinical crown and the broken line represents the root length

to evaluate the normality of the data. Two-way ANOVA was employed to evaluate the effects of tooth type and arch on the R/C ratio. The significance level was set at 0.05. Whenever a significant difference was observed a Tukey post-hoc test was implemented. All the statistical analyses were conducted via IBM SPSS Statistics for Windows Version 20 (IBM Corporation Software Group, New York, USA).

3. RESULTS

A total of 257 crowned teeth were included in this investigation (64 incisors, 22 canines, 88 premolars and 83 molars). For all the teeth, the mean R/C ratio was 1.43 (SD = 0.37) and ranged from 0.48 to 3.29. The Shapiro-Wilks test confirmed the normality of the data. Among all the teeth, canines had the lowest mean R/C ratio (mean = 1.34, SD = 0.33), followed by molars (mean = 1.38, SD = 0.34), incisors (mean = 1.39, and SD = 0.41) and premolars (mean = 1.54, and SD = 0.34). After investigating the effect of the tooth types on the overall R/C ratio, a significant difference was found between incisors and premolars (P = .04), and between premolars and molars (P = .01).

Within the maxillary arch, a significant difference in R/C ratio was found (P = .04) between the different teeth. However, the difference was significant only between premolars and molars (P = .02). Likewise, for the mandibular teeth, a significant difference in R/C ratio was found (P < .001). The difference was significant between incisors and premolars (P < .001), incisors and molars (P = .01), and canines and premolars (P = .01).

The maxillary teeth, especially the incisors, exhibited greater variation in R/C ratio than mandibular teeth (Table 1). Further, there is difference in the R/C ratio pattern between the maxillary teeth and the mandibular teeth (Fig. 2). However, after comparing the R/C ratio of the maxillary teeth (mean = 1.42, SD = 0.39) against the mandibular teeth (mean = 1.46, SD = 0.31), the two arches had a similar R/C ratio (P = .17). In general, for the anterior region, the maxillary teeth had a greater R/C ratio than the mandibular teeth. However, for the posterior region, the mandibular teeth had a greater R/C ratio than the maxillary teeth. The maxillary incisors had a significantly higher R/C ratio than the mandibular incisors (P < .001), and the maxillary molars had significantly lower R/C ratio than mandibular molars (P < .001). However, no significant difference was observed between the canines and the premolars between the different arches.

4. DISCUSSION

Although various R/C ratio values for the selection of teeth for single crown have been proposed in the literature, the recommendations are empirical in nature and lack the scientific literature support [1,2]. This study indicates that following the 1.5 R/C ratio is reasonable clinically and achievable in the majority of the cases. In addition, following the minimal R/C ratio criteria of 1 is feasible clinically. On the other hand, implementing an R/C ratio of 2 is very conservative and will restrict the selection of abutment teeth to receive crowns, and will potentially exclude teeth with reduced R/C ratios despite functioning normally [2]. This is even further illustrated by the mean R/C ratios of the different tooth categories, which were less than 2 for all of them.

In this study, the measured average R/C ratio was 1.4 which is similar to the reported R/C ratio of natural teeth. For young Korean individuals with unrestored dentition, the measured R/C ratio was in the range of 1.29-1.89 [10]. On the other hand, the R/C ratio of this study was significantly less than the R/C ratio reported by other studies [9,11]. In the Finnish population, Holtta et al. had found the R/C ratio of unrestored dentition to be in the range of 2.11-2.17 [9]. Similarly, Haghanifar et al. had found that the R/C ratio of Iranian population to range from 1.78-2.46 [11]. The differences of the outcome can be attributed to the design of the studies. For example, the studies by Holtta et al. and Haghanifar et al. quantified the anatomical R/C ratio by measuring

Table 1. The mean and standard deviation (SD) of the different tooth categories in the two arches

Maxilla	N	Mean	SD	Mandible	N	Mean	SD
Incisors	53	1.44	0.42	Incisors	11	1.17	0.27
Canines	12	1.41	0.35	Canines	10	1.25	0.29
Premolars	59	1.52	0.35	Premolars	29	1.60	0.31
Molars	34	1.22	0.38	Molars	49	1.49	0.27

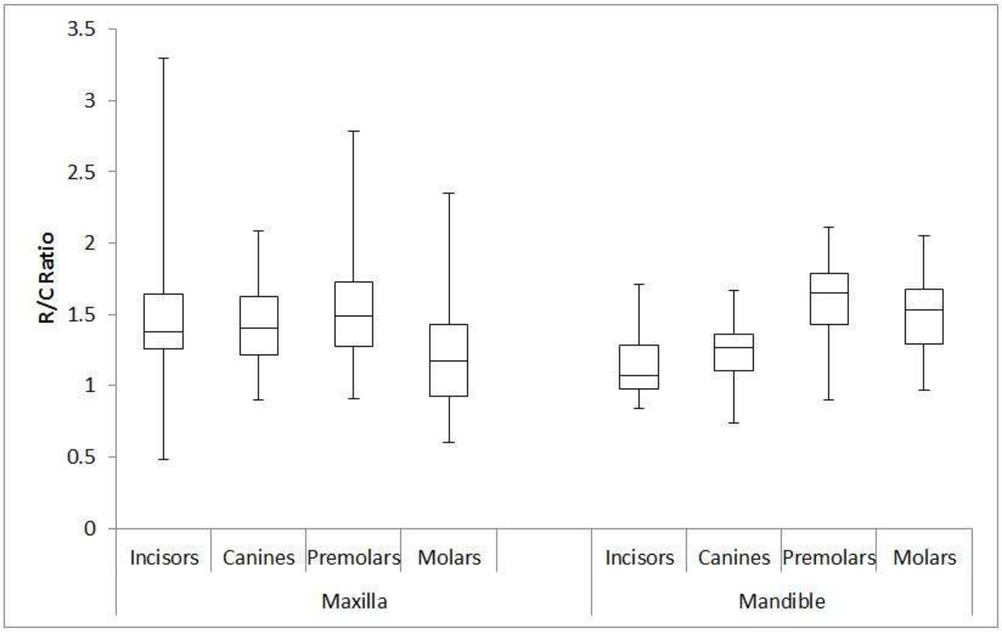

Fig. 2. Box plot diagram of the R/C ration values of the different tooth categories in the two arches

the crown length and root length from the cement-enamel junction. However, the present study and the study of Yun et al. measured the clinical R/C ratio by demarcating the clinical crown and the root using the radiographic bone crest level. Therefore, the method of measuring the R/C ratio will significantly influence the outcome, which should be taken into consideration when comparing different studies.

Comparison of R/C ratio values by tooth type found premolars exhibited significantly greater R/C ratios than incisors and molars. In general, this corresponds to the reported anatomical R/C ratio of natural teeth, where the premolars R/C ratio was greater than the R/C ratio of the other teeth [9,11]. Likewise, another investigation that had measured the clinical R/C ratio found the premolars R/C ratio exhibited a similar range to what has been reported in this study [10]. In contrast with the other studies, this study had found the canines to exhibit low R/C ratio. The studies on clinical and anatomical R/C ratios had found that canines tend to exhibit a relatively large R/C ratio. The difference in the results between this study and other studies is attributed to the potential distortion of the peri-apical radiograph. Although per-apical radiographs are among the most accurate dental radiographic images [12,13], the likelihood of distortion is still high [14]. This distortion appears to be more common for the anterior teeth, where the film with the holder is oriented parallel to the long axis of the tooth and may bend against the curvature of the palate. Minor alterations of the angle of the film against the tooth axis will result in considerable alteration of the radiographic tooth measurement [15]. As a result, the crown may be elongated on the radiograph, which will eventually reduce the R/C ratio. On the other hand, this distortion also explains the relatively reduced R/C ratios for the incisors in comparison with what has been reported by other studies [9-11]. There is a tendency for the R/C ratio of the molars of this study to exhibit lower values compared with other studies. Such an observation can be attributed to the evaluation of the teeth that were treated retrospectively and the likelihood of history of natural or pathological alveolar bone loss [16]. Since the analysis was conducted on crowned teeth, it is likely that they were restored due to the presence of a large restoration or other form of abnormality. Restored teeth, with subgingival and overhanging margins, were found to be associated with greater alveolar bone loss [17]. Furthermore, the earlier studies were conducted on young individuals, in which the R/C ratio is likely to be greater. As the individual ages, the R/C ratio will decrease [16].

After comparing the R/C ratio between the two arches, with the exception of the incisors, there was a tendency of the mandibular teeth to exhibit larger R/C ratios than maxillary teeth. This observation confirms the pattern detected by the anatomical [9] and clinical evaluations of R/C ratios [10]. For the incisors, this study observed a lower R/C ratio for the mandibular incisors compared with the maxillary incisors, which is opposite to the observations of the earlier studies [9-11]. The maxillary incisors R/C ratio values were generally similar to the observed values by Yun et al. [10]. However, the mandibular incisors were of considerably lower R/C ratio than for non-restored young dentitions. As mentioned earlier, this can be due to the retrospective nature of the evaluated teeth. In addition, the mandibular anterior teeth that were restored with crowns more likely had a history of condition that influenced the bone level. However, strong conclusions cannot be established due to the minimal number of mandibular incisors.

Despite the effect of the different tooth category and location on the arch, overall, there was similarity between the R/C ratios of the different teeth and the actual difference was of minimal magnitude. Although the R/C ratio is considered when selecting abutment teeth, there are other factors that affect the prognosis of abutment teeth that have greater literature support. These include the remaining tooth structure, periodontal health, pulpal status, root morphology and angulation [1,5]. These factors may be more important in the consideration of the prognosis and success of crowned abutments than the achievement of the ideal R/C ratio. This has been further supported by the clinical trials that had violated Ante's Law in the selection of abutment teeth, where healthy teeth with excessive loss of alveolar bone support were restored by cross-arch prosthesis. Interestingly, the studies did not reveal a relationship between the reduced periodontal support and further biological complications [18-20]. More importantly, these studies have been conducted on the use of maintained teeth in reduced but healthy periodontium as abutments in fixed partial dentures. Thus, the conclusion from the studies is that teeth with healthy, but reduced periodontium can be used to support fixed prostheses [18-20]. Similarly, a systematic review conducted indicated that fixed partial denture survival rates of patients with reduced but healthy periodontal support are comparable to that of individuals without severely periodontally compromised dentitions [21]. Through the evidence determined by these studies, it may be possible to provide crowned abutments on teeth that have reduced R/C ratios, as long as they have healthy periodontium. As a result, several authors pointed out that the importance of the R/C ratio is thought to be overrated by the earlier literature [1,21]. On the other hand, Tada et al reviewed the effect of R/C ratio on the survival of removable partial denture abutments over 7 years [22]. They found the abutment teeth to exhibit a compromised prognosis if the R/C ratio was below 0.67. However, the present study indicates that the clinicians easily tend to select R/C ratios greater than the risky R/C ratio reported by Tada et al. One of the reasons is that all the included patients were treated at a University hospital which may implement stricter criteria when selecting abutment teeth.

Although, to our knowledge, no earlier study had evaluated the R/C ratio of crowned teeth, this study suffers from few limitations such as the relatively limited number of teeth and peri-apical evaluation with the risk of distortion. Although the peri-apical radiograph is ranked as the most accurate 2D image [23,24], it does not provide information on the actual morphology of the root, and is still susceptible to distortion due to lack of standardization [25]. 3D imaging may provide more details on the tooth dimensions. However, 3D imaging will be difficult for teeth crowned with metallic restoration due to the scattering effect. Additional limitations can be due to not counting the effect of age, gender, ethnicity, history of the crowned tooth, and the initial periodontal support of the included tooth.

5. CONCLUSION

The mean R/C ratio in this study was similar to the guidelines proposed by literature recommending an R/C ratio of 1.5. When tooth type was considered, the R/C ratio differed between incisors and premolars, and between premolars and molars. With the exception of incisors and molars, no other interarch differences were found. However, the actual difference is minimal. Future studies and guidelines may consider the categorization of R/C ratios by tooth type.

CONSENT

It is not applicable.

ETHICAL APPROVAL

All authors hereby declare that the experiments of the investigation have been approved by the

Human Research Ethics Committee of Melbourne University (Ethics ID 1340995).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Grossmann Y, Sadan A. The prosthodontic concept of crown-to-root ratio: A review of the literature. J Prosthet Dent. 2005; 93:559-62.
2. Penny RE, Kraal JH. Crown-to-root ratio: Its significance in restorative dentistry. J Prosthet Dent. 1979;42:34-8.
3. The glossary of prosthodontic terms. J Prosthet Dent. 2005;94:10-92.
4. McGuire MK, Nunn ME. Prognosis versus actual outcome. III. The effectiveness of clinical parameters in accurately predicting tooth survival. J Periodontol. 1996;67:666-74.
5. Reynolds JM. Abutment selection for fixed prosthodontics. J Prosthet Dent. 1968; 19:483-8.
6. Yang HS, Chung HJ, Park YJ. Stress analysis of a cantilevered fixed partial denture with normal and reduced bone support. J Prosthet Dent. 1996;76:424-30.
7. Ericsson I, Lindhe J. Effect of longstanding jiggling on experimental marginal periodontitis in the beagle dog. J Clin Periodontol. 1982;9:497-503.
8. Harrel SK. Occlusal forces as a risk factor for periodontal disease. Periodontol. 2000. 2003;32:111-7.
9. Holtta P, Nystrom M, Evalahti M, Alaluusua S. Root-crown ratios of permanent teeth in a healthy finnish population assessed from panoramic radiographs. Eur J Orthod. 2004;26:491-7.
10. Yun HJ, Jeong JS, Pang NS, Kwon IK, Jung BY. Radiographic assessment of clinical root-crown ratios of permanent teeth in a healthy Korean population. J Adv Prosthodont. 2014;6:171-6.
11. Haghanifar S, Moudi E, Abbasi S, Bijani A, Poorsattar Bejeh Mir A, Ghasemi N. Root-crown ratio in permanent dentition using panoramic radiography in a selected Iranian population. J Dent. 2014;15:173-9.
12. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: Periapical vs panoramic films. Angle Orthod. 2001;71:185-9.
13. Gher ME, Richardson AC. The accuracy of dental radiographic techniques used for evaluation of implant fixture placement. Int J Periodontics Restorative Dent. 1995; 15:268-83.
14. Rushton VE, Horner K. A comparative study of radiographic quality with five periapical techniques in general dental practice. Dentomaxillofacial Radiol. 1994; 23:37-45.
15. Biggerstaff RH, Phillips JR. A quantitative comparison of paralleling long-cone and bisection-of-angle periapical radiography. Oral Surg Oral Med Oral Pathol. 1976; 62:673-7.
16. Hirschfeld L, Wasserman B. A long-term survey of tooth loss in 600 treated periodontal patients. J Periodontol. 1978; 49:225-37.
17. Lang NP, Kiel RA, Anderhalden K. Clinical and microbiological effects of subgingival restorations with overhanging or clinically perfect margins. J Clin Periodontol. 1983; 10:563-78.
18. Nyman S, Lindhe J, Lundgren D. The role of occlusion for the stability of fixed bridges in patients with reduced periodontal tissue support. J Clin Periodontol. 1975;2:53-66.
19. Yi SW, Ericsson I, Carlsson GE, Wennstrom JL. Long-term follow-up of cross-arch fixed partial dentures in patients with advanced periodontal destruction. Evaluation of the supporting tissues. Acta Odontol Scand. 1995;53:242-8.
20. Lundgren D, Nyman S, Heijl L, Carlsson GE. Functional analysis of fixed bridges on abutment teeth with reduced periodontal support. J Oral Rehabil. 1975;2:105-16.
21. Lulic M, Bragger U, Lang NP, Zwahlen M, Salvi GE. Ante's (1926) law revisited: A systematic review on survival rates and complications of fixed dental prostheses (FDPs) on severely reduced periodontal tissue support. Clin Oral Implants Res. 2007;18:63-72.
22. Tada S, Allen PF, Ikebe K, Zheng H, Shintani A, Maeda Y. The impact of the crown-root ratio on survival of abutment teeth for dentures. J Dent Res. 2015; 94:220S-5S.

23. Larheim TA, Svanaes DB. Reproducibility of rotational panoramic radiography: Mandibular linear dimensions and angles. Am J Orthod Dentofacial Orthop. 1986; 90:45-51.
24. Akesson L, Hakansson J, Rohlin M. Comparison of panoramic and intraoral radiography and pocket probing for the measurement of the marginal bone level. J Clin Periodontol. 1992;19:326-32.
25. Jepsen A. Root surface measurement and a method for x-ray determination of root surface area. Acta Odontol Scand. 1963; 21:35-46.

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