جامعة محمد بن راشد
للطب و العلوم الصحية

MOHAMMED BIN RASHID UNIVERSITY
OF MEDICINE AND HEALTH SCIENCES

A COMPARISON OF ARTIFICIAL CROWN DIMENSIONS TO NATURAL TEETH

Omar Abdullah Bamedhaf
DDS, Ajman University of Science and Technology, 2008

Presented to the Hamdan Bin Mohammed College of Dental Medicine
Mohammed Bin Rashid University of Medicine and Health Sciences
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Prosthodontics
2019

ABSTRACT

A comparison of artificial crown dimensions to natural teeth

Omar Abdullah Bamedhaf

Supervised by: Prof. Alexander Milosevic

Background: Crown dimensions can have a significant effect on the health of adjacent gingivae and on occlusal harmony. This study aimed to determine crown dimensions on artificial crowns and their contralateral natural teeth.

Materials and methods: Patients attending Dubai dental hospital with an artificial crown on a first or second molar and a sound contralateral tooth were invited to take part in this cross-sectional study. Clinical measures included the Basic Periodontal Examination and a check of inter-occlusal contacts with shimstock. Models were cast from polyvinylsiloxane impressions and scanned using Ortho Insight 3D (Motion View, MicronDental, USA). Mesio-distal (MD) and bucco-lingual (BL) measurements were made using the software and also by use of a Boley gauge (Premium Instruments, USA).

Results: A total of 16 participants (11 males; 5 females) with a mean age of 44 years were recruited to form a convenience sample. There was no difference in mean age by gender. A total of 20 pairs of crowns were included and most were in service for less than 5 years. There were 14 (70%) all-ceramic crowns, 5 (25%) metal-ceramic and 1 metal crown, with the upper left first molar being the most crowned tooth. The mean BL width of artificial crowns was significantly greater than the mean BL width of sound teeth using both methods of measurement ($p<0.01$). The mean BL widths were 11.57mm/11.17mm using the software and 11.49mm/11.07mm using the Boley gauge. The mean MD dimensions were not significantly different at 10.32mm on artificial crowns and 10.26mm on sound teeth using the software and 10.24mm and 10.16mm with the Boley gauge. Periodontal status was not significantly different between artificial crowns and sound teeth. A cusp tip to fossa relationship was the most

prevalent occlusal scheme with a modest correlation between artificial crowns and contralateral sound teeth (Spearman rho=+0.6, $p<0.05$).

Conclusion: Artificial crowns are wider bucco-lingually than their contralateral sound teeth. The bucco-lingual dimension of sound teeth should be measured, recorded and written in the laboratory prescription so that technicians can replicate this dimension more accurately.

DEDICATION

This thesis is dedicated to my beloved wife and parents, whose love, support and prayers made me complete this journey with success.

To my family and friends, for their constant support.

To those who inspired me in the field of dentistry and life.

DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization.

Name: Omar Abdullah Bamedhaf

Signature:

ACKNOWLEDGMENTS

All the praise to Allah, the Lord Almighty for putting me on the right track and removing all the obstacles from my way. The praise extends to my parents for raising me and encouraging me from the early years of my life to learn and seek improvement. Their support and being a role models shaped me to be a better man.

My deepest appreciation and gratitude go to my wife for supporting me during the last two years of my study in MBRU and the rest of my life, for motivating me to be the best man and for showing me how proud you are of me.

I would like to express my sincere appreciation to Prof Alexander Milosevic for supervising me, guiding me in my research dissertation, and for encouraging me to be proud of my work.

I would also like to thank and express my sincerest gratitude to the faculty in the Prosthodontics department. Dr. Moosa AbuZayda, Dr. Fatemeh Amir Rad and Dr. Tae-Ho Yoon for sharing their knowledge and facilitating my journey at Hamdan Bin Mohammed College of Dental Medicine.

My sincere thanks to my colleagues in Prosthodontics for sharing the last three years. Special thanks to Dr. Khalil Husain for being a great colleague and friend.

Finally, I would also like to extend my gratitude to every person walked into my life, supported me and did not forget me from his/ her prayers.

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

Unlike other tissues in the body, teeth lack the ability to regenerate lost tooth structure once it's lost due to caries, trauma or tooth wear such as attrition, abrasion or erosion. Maintaining the functional and aesthetic demands require restoring this missing tooth structure. Several restorative options are available to replace missing tooth structure and restore function. Among them is a fixed dental prosthesis such as full coverage crowns and partial coverage crowns.

In order to restore teeth with artificial crowns, teeth require reduction from the remaining tooth structure to create space for restoring material from the occlusal, axial and proximal surfaces. The amount of tooth reduction depends on the remaining tooth structure, the relationship to the adjacent and opposing teeth, and the restorative material requirements. The dimensions and contours of artificial crowns need to mimic the dimension and contour of the natural tooth in order to maintain the proper relation with neighbouring teeth and soft tissues and prevent any negative impact on periodontal health.

In addition to the impact on the biological environment, artificial crowns need to retain the functional capability of the dentition. Ideally, in inter-cuspal position, there will be a cusp to fossa relationship in which buccal cusps of mandibular posterior teeth will be in contact with the fossa of the maxillary posterior teeth. The guiding cusps of posterior teeth, lingual cusps of mandibular and buccal cusps of maxillary teeth, won't be involved in the inter-cuspal position. In an ideal occlusion, there should be a working side contact in lateral excursion movement and dis-occlusion in the non-working side. While in protrusion movement, there should be a dis-occlusion between the posterior teeth.[1] Restoring damaged teeth with fixed dental prostheses require paying attention to concepts of ideal occlusion and attempts to provide a restoration that can be in harmony and does not cause any functional disturbance.

The dimension and contour of artificial crowns depends on several factors. The amount of tooth reduction in preparation will play a big role in determining the contour and occlusal harmony. For example, metal crowns require a thickness of between 0.5-0.8mm,[2] and between 1.5mm

for metal-ceramic restorations.[3] On the other hand, full ceramic crowns require a minimum thickness of 1 mm.[4] Any discrepancy between the amount of tooth reduction and the chosen material to make the crown, can lead to the fabrication of an under-contoured or over-contoured crown. Recent advances in dental materials allow artificial crowns to be fabricated in thinner thickness.

The skills of the lab technician to fabricate an artificial crown that match the contra-lateral tooth and re-establish the correct relation with neighbouring teeth is crucial. Evaluation of the buccal contour of laminate veneers using a replica of the tooth as an anatomic reference showed a higher mean value of the buccal contour compared to the replica of the same tooth in all the samples.[5]

Another factor is related to the positional change of neighbouring teeth after extraction. Possible drifting of the adjacent teeth due to lack of proximal contact or supra-eruption of the opposing teeth in an attempt to re-establish a contact are two of the main consequences of losing tooth structure or teeth. These changes will limit the available space to restore the teeth leading to less than ideal dimension and contour of the artificial crowns.[6]

The fabrication of artificial crowns followed several theories and concepts over the years. Several theories were proposed for the design of crown contour. The gingival protection theory was proposed in 1920's.[7,8]According to the gingival protection theory, the crown should be fabricated in a way to prevent mechanical trauma to the marginal gingiva. The objective of the crown contour in this theory is to deflect the food away from the gingival margin by making the cervical third convex as under-contouring of the crown will lead to food impaction onto the gingival margin during mastication and subsequently will cause gingival inflammation. This theory led to the fabrication of over-contoured crowns. Several authors argued that the theory is not correct as the gingival margin will not be affected if the crown is contoured in a way that does not deflect the food away from the margin. There was no clinical nor histological change associated with under-contoured crowns, whereas over-contoured crowns were associated with gingival inflammation clinically and histologically.[9]Another study found that

gingival inflammation was associated with over-contoured artificial crowns while artificial crowns with correct contours did not exhibit an increase in inflammation at the gingiva .[10] The rationale of the gingival protection theory and the importance of contours to prevent food impaction onto gingival margins was also questioned by Herlands et al. Their argument was based on several observations such as the requirement of the food to be firm in order to be impacted, which is not the case as food is macerated during the masticatory process, the contour of the natural crown does not exceed 0.5 mm which is not enough to protect the gingiva from food impaction, the healthy gingiva around teeth with lost artificial despite the lack of crown contours to protect the gingiva, and the nature of gingival sulcus that is attached firmly to the crowns and difficult to be accessed by object, and the mechanism of crevicular fluid that flush out foreign objects from gingival sulcus.[11] In addition to lack of evidence to support the role of over-contoured crowns on gingival health, several authors found that gingival inflammation is caused by bacterial plaque rather than food impaction onto the gingival margin during mastication.[12,13]

The muscle action theory was promoted by Herlands[11] and Morris,[14] claiming that over-contoured crowns will prevent muscle action and thus the intimate contact of cheeks, lips and tongue with teeth and marginal gingiva preventing the cleansing role of muscles. They supported not over-contouring artificial crowns to allow the normal muscle action of self-cleansing and eliminating food stagnation on the gingival margin. Many authors disagreed with this theory due to the fact that the self-cleansing action of the muscles will not prevent gingivitis in the absence of oral hygiene.[13,15]

The third theory is related to facilitation of oral hygiene. As plaque is the main aetiology of periodontal disease,[13] provision of crowns that prevent the accumulation of plaque will have a positive impact in preventing the oral disease. Fabrication of artificial crowns based on this concept advises that the axial contour is flat rather than over-contoured. This concept is supported by the observation that under-contoured crowns promote gingival health, whereas over-contoured crowns were associated with negative gingival impact.[9]

2. REVIEW OF THE LITERATURE

2.1. Comparison between the bucco-lingual dimension of artifical crown and natural teeth.

Principles for the ideal crown contour include the bucco-lingual dimension of artificial crowns should not be larger than 1 mm of the natural bucco-lingual dimension at the cemental-enamel. The facial contour in the gingival third should not be extend more than 0.5 mm beyond the cemental-enamel junction. The lingual contour should be kept on the gingival third except mandibular molar where it should be placed in the middle third. The height of marginal ridge should match the height of the adjacent tooth. The biological width should be respected and the finish line is preferred to be supra-gingival except the highly aesthetic cases.[16]

Several studies compared the dimensions and contour of natural teeth and their contralateral teeth restored with artificial crowns. The bucco-lingual dimension of teeth restored with crowns and their contralateral natural tooth were evaluated by Parkinson who found that artificial crowns were wider compared to their contralateral teeth with the mean increase of porcelain fused to metal crowns equal to 0.71 mm, and 0.36 mm for full metal crowns. Similar differences were also found in laboratory cases with the contour of porcelain fused to metal crowns being 0.66 mm wider than contralateral teeth on laboratory models and 0.38 mm for full metal crowns. Plaque accumulation using mean plaque index was measured for the artificial crowns and their contralateral teeth. Mean plaque index of porcelain fused to metal crowns was 1.16 and 0.56 for their contralateral teeth while it was 1.24 for full cast metal and 0.72 for their contralateral teeth.[17]

In a paper assessing the coronal contours of artificial crowns, the buccal and lingual convexity of restorations were recommended not to extend more than half the thickness of the gingiva. The curvatures of the facial and lingual contours should be gradual to facilitate the self-cleansing mechanism by the lips, cheeks and tongue.[18]

The mean bucco-lingual width of maxillary posterior teeth increased from 9.46 mm prior to restore them with crowns to 10.44 mm after their restoration in a sample of 22 crowns. The mean in mandibular posterior teeth for 18 crowns increased from 8.01mm to 8.76 mm after restorations. The mean of incremental change in width for maxillary and mandibular posterior teeth was statistically significant.[19]

15 maxillary central incisors restored with either direct composite veneers, indirect composite veneers, or indirect ceramic veneers were compared to their dimensions prior to restoration. There was no significant dimensional difference between the different restorative treatments. The greatest dimension increase occurred at the gingival margin as 73% of the veneers were wider after treatment compared to their original dimension before treatment. The gingival regions were the least affected while the middle regions of 60% of the veneers showed an increase in the dimension after the treatment.[20]

Alhouri et al compared the buccal and lingual contours of 23 posterior full crown and their contralateral natural teeth. They found that the buccal contours were similar to the natural teeth in 70 % of the teeth while only 13% and 17% of the teeth were over-contoured and under-contoured respectively. On the other hand, the lingual contours were more affected with 43.5% of the restored teeth similar to the contralateral natural teeth, 26.1% over-contoured, and 21.7% were under-contoured. The comparison was also performed on 32 anterior full crowns that showed buccal over-contour on 12.5% of restorations and 25% on lingual contour.[21]

2.2. Effect of bucco-lingual contour on periodontal status

The impact of artificial crowns on periodontal condition is mainly related to plaque accumulation.[17] Bacterial plaque is considered the main cause of gingival inflammation as plaque accumulation is positively correlated with the presence of gingivitis.[22] Other causes of periodontal change due to artificial crowns are related to the compatibility of the dental materials and the impact of occlusion, which will be reviewed in the following sections.

The relationship between periodontal health and over-contoured restorations found that over-contoured restorations led to plaque retention and interfered with the effectiveness of personal oral hygiene.[23]

Over-contoured surfaces in mongrel dogs showed redness at the gingival margin after two weeks. After four weeks, in addition to redness at the gingival margin, 0.5 to 1 mm gingival proliferation occurred and there was tendency for bleeding on probing. Microscopically, teeth with over-contoured surfaces had higher concentration of polymorphonuclear leukocytes, lymphocytes and plasma cells at the tip of gingival margin. Whereas no significant changes on the under-contoured surfaces were found.[9]

Retention of plaque was more associated with axially over contoured crowns compared to crowns with less degree of contours. Crowns with lost temporary crowns were also associated with healthy gingival margins caused by the lack of contours, while adverse gingival reaction was associated with teeth restored with over contoured crowns.[12]

The effect of axial over-contoured walls on gingival status was measured in 42 pairs of crowned teeth in which over-contoured acrylic facing cemented to maxillary and mandibular premolars resulted in gingival inflammation around 59% of the mandibular of over-contoured crowns, Gingival tissue alteration, and greater crevicular fluid production compared to control sites. Whereas maxillary sites showed gingival tissue inflammation and alteration in 70% sites, and 50% of sites had greater gingival fluid production.[24]

In four patients who received bilateral provisional bridges, one under-contoured and the other over-contoured, no clinically significant changes were observed. Slight aesthetic differences were noted in three of the patients. The provisional bridges were only placed for four months which may justify the lack of significant changes.[25]

In comparing the effect of over-contoured wings of resin bonded bridges on gingival condition, there was minimal difference between the control and experiment sites during the period of optimal professional and oral hygiene care. In the period of no oral hygiene measures, the

plaque and bleeding indices had increased for both sites but was greater in the experimental sites although the difference was not significant.[26]

Procera titanium crowns with 3 different crown contours were compared to contralateral natural teeth for quality and quantity of plaque. Plaque accumulation was lower for all Procera titanium crowns a week after normal oral hygiene and 2 days after no oral hygiene. Microbiologically, control teeth were associated with more colony forming unit compared to crowned teeth but this difference was not statistically significant.[27]

In clinical evaluation of different crown contours on periodontal tissue in beagle dogs. Plaque and gingival indices for the 30 degrees and 50 degrees over contoured crowns were increased but the difference was not statistically significant. Whereas control teeth and normal contour crowns had minor changes. The gingival crevicular fluid flow was significantly higher for the 30 degrees and 50 degrees over contoured crowns compared to normal contour and control group.[28]

In beagle dogs, the second and third premolars were restored with single gold crowns in 3 quadrants while the fourth quadrant acted as a control group. The gold crowns had three different emergence profiles which were normal contour, over-contour by 30º, and over-contour by 50º. 3 months microbiological evaluation showed that all crowned teeth had an increase in bacterial counts compared to baseline despite the intensive oral hygiene intervention. At 5 months evaluation, there was no significant difference in bacterial count between control group, normal contour and 50º over-contoured crowns, whereas the 30º group showed a significantly higher bacterial count.[29]

2.3. Effect of fixed dental prosthesis on periodontal health

Biopsy from interdental papillary tissues adjacent to artificial crowns had more inflammatory cells compared to gingiva adjacent to non-restored teeth despite both gingival tissues appear clinically normal. The highest inflammatory cells were associated with inflamed gingiva adjacent to restored teeth.[30]

The crevicular fluid flow rate of crowned and non-restored teeth in 32 patients was measured with a HAR-600 gingival crevice fluid meter. The flow rate for non-restored teeth was 0.030 µl/min mesially and 0.038 µl/min distally, while it was 0.064 µl/min mesially and 0.074 µl/min distally for crowned teeth. Crevicular flow rate was significantly higher in crowned teeth compared to non-restored, whilst the gingival index was higher on crowned teeth, 0.71 mesially and 0.74 distally, compared to 0.11 mesially and 0.14 distally for the non-restored teeth.[31]

Gingival inflammation around teeth restored with full crowns compared to control teeth, found no significant difference in the mean gingival crevicular fluid between restored teeth and the non-restored teeth. Mean crevicular fluid volume associated with sub-gingival margin crown was 6.7 according to periotron reading, 3.9 for crowns with margins at gingival crest, and 6.5 for supra-gingival margin group. The difference was not significant when comparing the full crowns based on the margin placement.[32]

The periodontal response to 82 all-ceramic crowns were compared to contralateral teeth in 64 patients after an average of 16.27 months. All the measured parameters, plaque index, gingival index and mean pocket depth of crowned teeth showed less favourable scores (0.35, 0.41, and 1.42 respectively) compared to contralateral teeth (0.72, 0.23, and 0.86). Overall probing depth was the only statistically significant difference between crowned teeth and natural teeth, although pocket depth around crowned teeth was < 3 mm.[33]

Gingival inflammation and probing depths were higher around crown and bridge abutments compared to non-restored teeth although teeth restored with porcelain were associated with lower plaque score compared to natural teeth.[34]

The effect of fixed dental prostheses on periodontal health was also evaluated around abutments in 78 females who had fixed partial dentures placed by senior students at King Saud University. The mean plaque score on abutment teeth was significantly higher than the control teeth. The mean gingival score was also significantly higher for abutment teeth (1.46) compared to non-abutment teeth (0.76). Probing pocket depth was also significantly higher for abutment teeth compared to non-abutment teeth (3.09 mm versus 2.3 mm).[35]

The periodontal status of teeth restored with single crowns and their contralateral natural teeth in 74 patients was comparable for probing depth, clinical attachment level and bleeding on probing whilst only plaque index was higher percentage around natural teeth (58.1%) compared to contralateral crowned teeth (29.7%).[36]

2.4. Effect of margin position on periodontal status

The effect of different margin locations on gingival tissue in dogs was assessed from histological samples of inflamed gingivae. Crowns with gum level margins showed the least inflammation, followed by crowns with sub-gingival margins. Crowns with supra-gingival margins were associated with the highest degree of inflammation which was 32.58% for moderate to severe inflammation compared to 20.45% and 2.27% for sub-gingival margin and at crest level respectively. There was a significant level of difference at 0.001 when comparing supra-gingival and sub-gingival groups to control group, and the difference between the group with margin at crest to control group was not statistically significant different.[37]

146 bridge abutments in 73 patients were divided to two groups according to whether individuals were instructed on how to improve their oral hygiene or not. The abutment teeth were compared to contralateral natural teeth for different periodontal parameters. The mean plaque score on abutment teeth of the instructed group was 0.86 which was statistically lower than the mean plaque index of abutment teeth in the non-instructed group (1.21). Similarly, the mean gingival score of the instructed group was 1.06 which was significantly lower than 1.33 in the non-instructed group. Mean gingival and plaque scores on crown margins 2mm above

the gingiva were not significantly different between abutment teeth and control teeth. The mean plaque score on sub-gingival crowns was significantly greater on interproximal areas of abutments compared to control teeth, while there was no significant difference in buccal and lingual areas. Buccal and interproximal areas of abutment teeth with sub-gingival crown margins had significantly greater mean gingival scores compared to control teeth. Pocket depth measurements showed no significant difference between abutment teeth and control teeth. There was also no significant difference in pocket depth between the instructed group and non-instructed group.[38]

A comparison of 242 abutment teeth to their contralateral natural teeth showed no statistically significant difference in mean plaque score for abutments with supra-gingival crown margins compared to their contralateral natural teeth. Mean plaque score of sub-gingival crown margins was significantly greater than contralateral teeth. The mean gingival score of full coverage crowns regardless of margin location or the provision of oral hygiene instruction was significantly higher than contralateral natural teeth. Mean gingival score on partial coverage crowns was not statistically different than natural contralateral crowns. Mean pocket depth was also significantly higher on full coverage crowns compared to contralateral natural teeth, while the difference in mean plaque score was not statistically different for partial coverage crowns.[39]

In an animal study to evaluate the gingival reaction to dental restorations, 21 full gold crowns, 6 micro-bond crowns, 15 class V gold inlays, and 9 class V heat cure acrylic inlays with different margin locations were fabricated for 2 dogs and 3 monkeys. Gingival inflammation was present in 5 out of 18 crowns with sub-gingival margins, while the remaining crowns had a gingival condition similar to the adjacent unprepared teeth. Class V gold inlays with sub-gingival margins had the least gingival response while class V acrylic inlays had the poorest result in terms of gingival reaction. There was also no difference in gingival conditions between restorations with supra-gingival margins and adjacent unprepared teeth.[40]

An interesting study design had twelve gold crowns with half of the facial margin placed supra-gingivally and the other half placed sub-gingivally. Evaluation after three years revealed no

difference in gingival health, pocket depth and plaque accumulation. The author concluded that the fit of the crown margin and preventive care are more important to gingival health than the position of the finish line.[41]

The effect of sub-gingival margins on the periodontal condition was evaluated by comparing 66 anterior crowns with sub-gingival margins to contralateral natural teeth in 59 patients. The mean plaque score of crowned teeth was 0.14 which was significantly lower than the natural teeth (0.65). The mean gingival score was significantly greater for crowned teeth (1.23) compared to 0.33 for natural teeth. The mean crevice depth was also statistically different as it was 1.01 mm for crowned teeth and 0.91 mm for natural teeth.[42]

The effect of sub-gingival margins on pocket depth of 111 cast gold crowns were compared to their contralateral natural teeth. The mean pocket depth for cast crowns was 3.4 mm which was significantly greater than 2.7 mm for contralateral natural teeth. There was no relationship between pocket depth and frequency of brushing adjacent to cast crowns. In contralateral natural teeth, a reduced frequency of brushing was associated with an increase in pocket depth.[43]

In a five year follow-up study of 32 single crowns and 357 bridge abutments in 114 patients, an annual periodontal examination was performed that included plaque index, gingival index, and pocket depth. At the time of cementation, 65% of crowned surfaces had sub-gingival margins, 16% at gingival level, and 19% had supra-gingival margin. After 5 years follow-up, sub-gingival margin had decreased to 41%, while crowns margins at gingival level increased to 30% and supra-gingival margins to 29%. The average loss of attachment was 1.2 mm for the sub-gingival crown margin group, 0.8 mm for crown margin at gingival level, and 0.6 mm for supra-gingival crown margin. At the initial examination, pocket depth of 2 mm or less was associated with 76-83% of teeth regardless of the location of crowns margin. At 5 year follow-up, mean pocket depth increased for sub-gingival margin location from 2.1 mm to 2.7 mm, and from 2.1 mm to 2.4 mm for surfaces with the margins at gingival level, while pocket depth for margins with a supra-gingival position remained the same at 2.0 mm. The frequency of plaque

index scores 2 and 3 slightly decreased over the 5 years follow-up from 22% to 18%. The frequency of gingival index scores 2 and 3 remained the same over the 5 year follow-up at 45% while score 0 improved from 6% to 15%. A gingival index score of 0 occurred in 37% and 14% of supra-gingival margins and gingival margin respectively, while only 1% of sub-gingival crown margins had a score 0. The frequency of gingival index score 3 was associated more with sub-gingival crown margins at 9% while for crown margins at gingival level or supra-gingival it was 1%.[44]

The effect of crown margins on the periodontal condition of periodontally supervised patients, 5 patients with 47 crowned teeth were examined 1 year after receiving prosthetic treatment. The plaque score for the supra-gingival margin group increased slightly over the year from 0.26±0.32 to 0.34±0.42 while the score for gingival index decreased over the year from 0.31±0.25 to 0.17±0.27. Crowns with margins at the gingival level had a slightly lower score for plaque index over the year from 0.24±0.26 to 0.15±0.24. Pocket depth decreased over the year for the supra-gingival margin group and increased for the group with margins at gingival level.[45]

In an evaluation of 423 crowns (355 sub-gingival margins and 68 supra-gingival margins), the mean plaque score for the sub-gingival margin group was significantly higher than the supra-gingival margin group. Although the difference was not statistically significant, the chances of bleeding on probing was 6 times greater for the sub-gingival group compared to the supra-gingival group. In comparing crowns to natural teeth, bleeding on probing and recession were significantly greater for the sub-gingival margin group only.[46]

Surfaces of fixed dental prosthesis in 19 patients were divided according to the crown margin location; at gingival level, supra-gingival and sub-gingival. Evaluations were performed 6 months and after 1 year after restoration and included gingival index, plaque index, probing depth and sulcus fluid flow rate. There were highly significant differences between the three groups in gingival index and sulcus fluid flow at the first examination. The sub-gingival group scored the highest gingival index with a mean of 0.93 compared to 0.23 in the supra-gingival

group, and 0.55 for the group with gingival level margins. Sulcus fluid flow for sub-gingival group was 2.4 times higher than gingival margin group and 3.2 times higher than supra-gingival group. Plaque score and probing depth were significantly greater in the sub-gingival group compared to the supra-gingival and at gingival level. at the second examination, gingival index, pocket depth and sulcus fluid flow rate were significantly greater in the sub-gingival group compared to the other two groups. In comparing between the first and second examination, significant improvement in all clinical parameters occurred for supra-gingival group. sub-gingival group showed an improvement but it was not significant. Finally, in the group with crown margins at gingival level, gingival and plaque indices showed an improvement which was significant for plaque index. Probing depth and sulcus fluid flow rate had worse scores at the second examination which was significant for sulcus fluid flow rate.[47]

Marginal discrepancy on artificial crown was significantly correlated to gingival index score and crevicular fluid volume, while marginal discrepancy was not significantly correlated to pocket depth. Periodontal status was not influenced by the age of restorations nor the type.[48]

Gingival index score for horizontally over-extended and under-extended marginal configuration was significantly greater compared to their contralateral natural teeth, but bleeding on probing and pocket depth on over-extended and under-extended crown margins were not different when compared to their contralateral natural teeth. Surprisingly sub-gingival crown margins and at-crest/supra-gingival margins did not result in any significant difference in long term periodontal parameters. In short term, at-crest/supra-gingival margin had statistically significant greater plaque index compared to sub-gingival margins, while the difference was greater for sub-gingival group in gingival index. Pocket depth was statistically greater for the group with 2-3 mm sub-gingival margins compared to at/crest and supra-gingival group, and the group with 1mm sub-gingival margins.[49]

In a 15 years longitudinal study that assessed periodontal condition and oral hygiene in 102 patients, 343 abutment teeth were compared to 525 natural teeth which served as a control group. Clinical parameters included plaque and gingival indices and pocket depth which were

recorded for the patients over the follow-up period. Plaque index scores of 2 and 3 did not differ between abutment teeth and control teeth over the follow-up period as both groups had 21% and 27% at baseline and at 15 year follow-up. Bleeding on probing was more frequent on abutment teeth at 30% at 15 year follow-up compared to 22% in the control group. The prevalence of gingival index scores 2 and 3 was higher at all follow-up periods when crown margins were placed sub-gingivally compared to supra-gingivally or at gingival level. The mean pocket depth increased for abutment teeth from 2.1 mm to 2.4 mm at 5 year follow-up while it decreased for control teeth over the same period from 2.3 mm to 2.2 mm. At 15 year follow-up, the mean pocket depth for abutment teeth and control teeth was 2.4 mm and 2.2 mm respectively. The study also examined the development of carious lesions on abutment teeth over the follow-up period. At 5 year follow-up, 3.4% of abutments developed caries with a sub-gingival margin, 2.1% for abutments with crown margin at gingival level, and 3.7% for abutments with supra-gingival margin. At 10 year follow-up, the percentage increased to 10.7% for sub-gingival margin, 7.6% for abutments with crown margins at the gingiva margins, and 9.9% for supra-gingival crown margins. At 15 year follow-up, the highest percentage of carious lesions was associated with abutment teeth with crown margins at gingival level which was 15.8%, followed by 14.5% for abutment teeth with crown margin at supra-gingival level, and 10.2% for abutment teeth with crown margin at sub-gingival margin.[50]

A retrospective study of forty patients evaluated visible plaque, gingival bleeding, probing pocket depth and clinical attachment level three to five years after crown restoration. 240 crowns were included with 151 crowns having sub-gingival margins and 89 crowns with supra-gingival margins. 21.7% were considered ill fitted while 78.3% considered well fitted. Visible plaque around crowned teeth was 30.42% which was significantly less than around natural teeth which had 49.17%. But gingival bleeding index and probing pocket depth were significantly higher on crowned teeth compared to control teeth.[51]

Among 100 patients who received ceramic crowns, 64 had supra-gingival preparations and 36 had sub-gingival margins. The percentage of bleeding on probing for supra-gingival margins

was 20% for PFM crowns and 14% for all ceramic crowns which was significantly lower than sub-gingival margins at 65% for PFM crowns and 75% for all ceramic crowns. Plaque and probing depth indices were also statistically significant higher when comparing sub-gingival finish line to supra-gingival finish line. Regardless of margin location, there was no statistically significant difference between all ceramic crowns and PFM crowns in terms of bleeding on probing, plaque index and pocket depth index.[52]

The influence of intracrevicular crown margins on gingival health in 30 patients who received single crowns made from different materials on natural teeth or implants were compared to natural teeth 6 months after their final restoration. There was no significant difference between restored teeth and natural teeth for plaque score, and signs of gingival inflammation which were redness, bleeding and swelling.[53]

In a prospective study that included 480 crowns in 240 patients, there was no significant difference between crowns and uncrowned teeth in plaque accumulation. The probability of plaque on control teeth was twice more than artificial crowns. Probability of bleeding on probing was approximately twice more for sub-gingival margin than supra-gingival margin. Finally, the used alloys did not influence gingival bleeding nor plaque score.[54]

50 metal crowns and 50 porcelain fused to metal crowns in 100 patients were compared to their contralateral natural teeth. 97% of porcelain fused to metal crowns with supra-gingival margins had no bleeding on probing compared to 73% of porcelain fused to metal crowns with sub-gingival crown margins. Similarly, 100% of metal crowns with supra-gingival crown margins had no bleeding on probing while 75% of metal crowns with sub-gingival crown margins had no bleeding on probing. Plaque scores were significantly lower for supra-gingival margins compared to sub-gingival margins. 97% of porcelain fused to metal crown and 100% of metal crowns with supra-gingival margin scored 0 for pocket depth. On the other hand, 73% of porcelain fused to metal crowns and 75% of metal crowns with sub-gingival margin scored 0 for pocket depth. There was also no statistically significant difference between porcelain fused to metal crowns and metal crowns in all the measured periodontal parameters.[55]

The effect of finish line position was measured in 10 patients before and after non-surgical periodontal therapy. Plaque index scores reduced after non-surgical periodontal therapy from 53% to 26.7% for supra-gingival margins, 53% to 40% for margins at the gingival level, and 70% to 36.7% for sub-gingival margins. There was also a significant reduction in bleeding index between the two examinations for all finish lines. Bleeding index scores after non-surgical periodontal therapy for supra-gingival finish lines was 7% which was significantly lower than sub-gingival finish lines at 22%. There was no statistically significant difference before and after non-surgical periodontal therapy in probing pocket depth, clinical attachment level and gingival recession among the different finish lines. Gingival crevicular flow reduced after non-surgical periodontal therapy but the reduction was not statistically significant.[56]

Plaque index, gingival index and pocket depth significantly increased after 1 year on crowned teeth with either a deep chamfer or a feather edge, both margins being sub-gingival. There was no difference between both finish lines for plaque index and pocket depth, but feather edge finish line resulted in more bleeding.[57]

2.5. Effect of crown material on periodontal status

In an experiment to compare the plaque retaining capacity of 4 different materials, type III gold, ceramo-metal restoration. porcelain and acrylic resin, it was reported that significantly greater plaque scores were found on type III gold than porcelain. Acrylic resin had also statistically significant lower plaque retaining capacity than type III gold and gold alloy for ceramco-metal restoration. The difference in plaque retaining capacity between porcelain and acrylic resin was not statistically significant different.[58]

Morphologic changes of gingiva were compared between a group of 32 patients who received porcelain bonded to gold crowns to 25 periodontally healthy patients with no artificial crowns. Clinically, gingiva adjacent to natural teeth in the control group was considered healthy for all the patients. On the other hand, 14 out of 69 gingival regions adjacent to crowned teeth were considered healthy, 24 regions had mild gingivitis, and 31 had severe gingivitis. Capillary

dilatation of more than 20 µ was associated with 23.3% of the crowned group compared to 3.9% of the non-crowned group. Capillary loop morphology was normal in 53.8% of the control group and 2% of the experiment group, and the complex form of capillary loop was not present in control group while 21.7% of experiment group presented with complex form.[59]

In a study to measure bacterial growth and compare it between different restorative materials, pontics of fixed dental prostheses were fabricated in a way to temporary hold specimens of the restorative material in close proximity to the gingival tissue during the experimental period. There was no statistically significant difference between the restorative materials (acrylic, gold, amalgam, and porcelain) in terms of bacterial count, yet acrylic resin was associated with the least bacterial growth. The significant difference was present when comparing the acrylic to enamel which had the highest bacterial count.[60]

The mean plaque score of each crown type was calculated as a percentage from the mean plaque score of the quadrant. Full ceramic crowns had the lowest percentage of crown to quadrant plaque index score at 32%, followed by ceramo-metal crowns that scored 90%. Cast gold crowns and acrylic resin veneer crowns scored 148% and 152% respectively.[61]

The mean plaque index score on crowned teeth was 0.20 which was statistically lower than uncrowned teeth (0.27). Mean calculus index was also statistically lower for crowned teeth compared to uncrowned teeth. On the other hand, mean gingival index and mean probing depth were statistically higher for crowned teeth compared to uncrowned teeth.[62]

In a randomised double-blind study to evaluate the gingival reaction to cast and sintered metal in 12 patients, mean sulcus fluid flow rate was measured for crowned teeth and adjacent natural teeth. At baseline there was no difference between natural teeth and crowned teeth in mean sulcus fluid flow rate. After two months, the difference in mean sulcus flow rate between crowned teeth regardless of the material type was statistically significantly higher than adjacent natural teeth, but mean sulcus flow rate was not different between cast and sintered metal,[63]

Plaque adherence to different dental materials, amalgam, composite, cast gold and three different ceramic materials, was evaluated after 24 hours incubation with cariogenic bacteria

and sucrose. The amount of bacteria adherent to the surfaces was the highest for amalgam specimens 48373.6 Disintegrations per minute (dpm), followed by composite (28270.6) and cast gold (10742.9) with the least adherent bacterial count on the different ceramics. Bacterial adherence to amalgam and composite after the final polish decreased to less than one tenth compared to rough specimens. On the other hand, cast gold specimen had the highest bacterial adherence compared to other dental materials after the final polish.[64]

In a prospective blinded randomized clinical trial comparing the effect of galvano-ceramic and metal-ceramic crowns on periodontal tissues, there was no statistically significant difference at baseline between the groups in plaque and gingival indices or crevicular fluid flow rate. At 12 and 24 months follow-up, mean plaque and gingival indices were significantly lower for galvano-ceramic crowns compared to metal-ceramic. In addition to that, pocket depth and crevicular fluid flow rate were not statistically different between both groups at 12 months follow-up. Crevicular fluid flow rate at 24 months follow up became significantly lower for galvano-ceramic group compared to metal-ceramic while pocket depth showed no significant difference.[65]

In a randomized controlled trial to evaluate the performance of zirconia ceramic and compare it to metal ceramic, 10 patients with zirconia ceramic cantilever fixed dental prostheses and 9 patients with metal ceramic were followed up for 3 years. Plaque and gingival indices were slightly higher after 3 years for both groups compared to baseline but the difference was not statistically significant. Pocket probing depth was also not statistically significant different compared to baseline in either group. In addition to that, there was no significant difference between zirconia ceramic and metal ceramic groups in all the measured clinical parameters.[66]

In a 3 year randomized controlled clinical trial comparing pressed or layered veneering ceramic on posterior 3 unit zirconia fixed dental prostheses, there was no statistically significantly difference in plaque, pocket probing depth and bleeding on probing.[67]

In an in vitro experiment to evaluate Streptococcus mutans adhesion to ceramic material, 15 specimens were divided in to three groups of 5 sample each of IPS e.max press, polished

feldspathic porcelain, and human dental enamel block. The three groups were exposed to bacteria for one hour before culturing on blood agar. The mean bacterial count of Streptococcus mutans on enamel blocks was 24.4±8.44 colonies/mm^2 which was significantly higher than IPS e.max and polished feldspathic porcelain, 5.6±2.35 and 5.8±1.92 colonies/mm^2 respectively. The difference in Streptococcus mutans adhesion between IPS e.max and polished feldspathic groups was not significant.[68]

Gingival crevicular fluid, gingival index and pocket depth were measured in 80 patients, of whom 40 patients received porcelain fused to cobalt-chromium alloy crowns and the other 40 patient received porcelain fused to gold alloy crowns. In the gold alloy group, gingival crevicular fluid volume was (0.66±0.14) μL which was lower than cobalt-chromium alloy group (0.83±0.16) μL. Gingival index score (024±0.05) and pocket depth (1.84±0.12 mm) were also lower in the gold alloy group compared to 1.03±0.21 for gingival index and 2.11±0.14 mm for pocket depth for cobalt-chromium alloy group.[69]

Measurement of gingival crevicular fluid, pocket depth, pocket index and bleeding on probing was performed on 59 pairs of crowned teeth and natural teeth that served as controls in 49 patients. The crowned teeth were grouped according to the ceramic material. The first group had lithium disilicate ceramic crowns; the second group were restored with yttria-stabilized zirconia frameworks and veneered by a pressed veneering system; the crowns in the third group were restored with yttria-stabilized zirconia framework and a layering ceramic. Interleukin and MMP-8 concentration from the gingival crevicular fluid of the 59 pairs was not statistically different between the crowned teeth and control teeth. There was also no difference among the three different material groups. 19% of crowned teeth in the first group had a positive score for bleeding on probing while the control group had 10%. The second group had a higher percentage of bleeding on probing which was 27% for crowned teeth and 23% for the control group while the third group had the highest response as it was 45% for crowned teeth and 54% for their control group. There was no difference in plaque index and probing depth between crowned teeth and the controls.[70]

Microbiological evaluation by swabbing and culturing from artificial crowns in 17 patients made of different materials was performed to evaluate bacterial accumulation and plaque formation. Mean of Streptococcus sanguineous colonies was statistically significant different between the groups, in gold crowns group it was 14.85 colony forming units while it was 6.16 for Lithium dislocate crowns group. The least amount of Streptococcus sanguineous colonies was associated with zirconia which was 3.25.[71]

Another study looked into Streptococcus mutans adhesion to glazed IPS e.max and glazed feldspathic porcelain using 5 blocks of each material and compared that to the control group of enamel block. There was no significant difference between glazed IPS e.max and glazed feldspathic porcelain. The mean Streptococcus mutans adhesion to enamel was 24.4±8.44 colonies/mm^2 which was significantly higher than to glazed IPS e.max and glazed feldspathic porcelain groups, 1.8±0.83 and 1.4±0.54 respectively.[72]

Plaque and gingival indices were measured in 60 patients who received 31 single crowns and 37 bridges with oral hygiene instruction given at baseline, 14 days later and 3 months from the start of the study. The sample included 43 teeth restored with ceramic fused to metal and 25 teeth restored with acrylic veneered to metal. The plaque index for ceramic fused to metal crowns after 14 days of placement was 0.6818 which was statistically lower than at baseline (0.8636). The difference in plaque index between baseline and the third examination, and between the second and third was not statistically significant. Single crowns made from acrylic veneered to metal did not show any significant difference between the three examinations for plaque index. Plaque index scores for fixed partial dentures made from ceramic fused to metal was statistically different between first and second examination similar to single crowns made from the same material. Fixed partial dentures made from acrylic veneered metal did not have any statistically difference between the three examinations similar to single crowns made from the same material. Fixed partial dentures made of acrylic veneered metal had a significantly increased gingival index between baseline and the second examination at 14 days.[73]

The interleukin one beta concentration of crevicular fluid was measured in twenty patients who had single teeth restored with artificial crown made of different materials which were compared to the contralateral natural teeth. Zirconia crowns were associated with the least interleukin one beta concentration which was 84.66 picograms, followed by ceramic crowns at 106.22 picograms and 136.93 for metal crowns. The difference in interleukin one beta concentration was statistically significant between the three different crowns.[74]

2.6. Effect of occlusion on periodontal health

Functional disturbance in relation to occlusion may lead to excessive forces and non-axial load on teeth. The association between occlusal forces and periodontal disease has been studied in the literature, and the outcome of these studies was inconclusive. Stillman[75] was one of the first authors to associate excessive occlusal force with the initiation of periodontal disease and supported the need for occlusal adjustment to prevent periodontal destruction. Several other authors could not find a correlation between excessive occlusal force and periodontal disease.[76-77] On the other hand, considered excessive occlusal forces was considered as a contributing factor in the progress of periodontal destruction.[78]

Probing depth was significantly greater on teeth with occlusal interference compared to teeth without occlusal interferences. Smokers were also associated with significantly greater pocket depth compared to non-smokers.[79]

The effect of occlusal interference on gingival tissues found that the average gingival width was 3.28 mm on the group with no occlusal discrepancy and it was 3.33 mm for the group with occlusal discrepancy. But this was not statistically significant.[80]

The effect of premature contacts in centric relation on periodontal tissues in 46 periodontally healthy subjects with premature contact in centric relation on one side and without premature contact in centric relation on the other side were evaluated. There was no significant difference in clinical attachment loss between teeth with premature contacts in centric relation and teeth without it.[81]

The impact of occlusion on periodontal tissue was assessed in a study that evaluated 100 subjects for occlusal contacts on the non-working side during lateral excursion and correlated clinical parameters related to periodontal health. The authors did not find a significant difference in probing depth and clinical attachment level for subjects with and without non-working side contact.[82]

The association of occlusal contacts on teeth with periodontal pockets reported that teeth with centric premature contacts had greater probing depth by 0.9 mm compared to teeth without premature contact. Probing depth was significantly greater on posterior teeth with contact during protrusive movement compared with posterior teeth with no contact. On lateral excursion movement, teeth with contact on working side had no significant difference in probing depth compared to teeth with no contact. On the other hand, teeth with contact on non-working side had significantly greater probing depth compared to teeth with no contact on non-working side.[83]

The impact of high occlusal forces on periodontal tissues in 30 patients with untreated chronic periodontitis found that high occlusal force was associated with greater pocket depth and bleeding on probing compared to teeth without high occlusal forces. Clinical attachment loss and tooth mobility did not differ between teeth with or without high occlusal.[84]

The effect of occlusal trauma on periodontal health in 41 patients over 1 year found that pocket depth of teeth without occlusal trauma was significantly lower than teeth with untreated occlusal trauma and they also had a significantly better prognosis than teeth with untreated occlusal trauma. Finally, the mean increase in pocket depth was significantly higher on teeth with untreated occlusal trauma compared to teeth without occlusal trauma.[85]

3. AIMS

The following study aims to measure the dimensions of artificial crowns and their contralateral natural teeth.

Objectives:

1. To compare the bucco-lingual and mesio-distal dimension of artificial crowns and their contralateral natural teeth.
2. To compare the periodontal condition around artificial crowns and their contralateral natural teeth.
3. To compare the effect of margin position on periodontal health.

The null hypothesis states that there is no difference in crown dimension between artificial and natural teeth.

4. MATERIALS AND METHODS

This was a cross-sectional study which was carried out in 2018 among visiting patients to Dubai Dental clinic. Patients who had artificial crowns and contralateral natural teeth (not crowned) were not randomly selected but selected as a convenience sample.

Based on the figures from the study by Parkinson et al [17], A total of 20 pairs (20 artificial crowns and 20 contralateral natural teeth) were to be included for a matched sample.

The sample size formula for matched samples is shown below.

$$n = \left(\frac{Z\,\delta}{E}\right)^2$$

And E given by

$$E = Z\,\frac{\delta}{\sqrt{n}}$$

Where Z is the quartile of 95% which is equal to 1.96 and δ is the standard deviation of the difference between the two samples and E the width of 95% CI of the difference.

Only patients with an artificial single crown in one quadrant and unrestored contralateral tooth were included. In addition to that, artificial crowns must be either a first or second molar. Abutment teeth in fixed dental prosthesis were not included.

An English (Appendix 1) or Arabic (Appendix 2) consent form was discussed with the patient to explain the aim of the clinical examination and data collection. The data were recorded on a data collection sheet (appendix 3) by the researcher. A clinical examination using a UNC- 15 probe was performed to measure periodontal pocket depth and bleeding on probing. Instead of using the 6 pocket points for each tooth during the analysis, the deepest pocket depth of natural tooth and artificial crowns were recorded. The equivalent of Basic Periodontal Examination of the pocket depth was also used. Shimstock foil (ALMORE international, Oregan, United States of America) was used to evaluate the occlusal contact indicating whether there was a tight contact (tearing the foil when it's pulled out while the patient in closing in inter-cuspal), loose contact (pulling the foil will not lead to tear but it will leave a mark on the foil), and no contact

(foil pulls out without any contact due to lack of occlusal contact). A full metal tray was used for intra-oral impressions. Vinyl Polysiloxane impression material light body (3M ESPE Express) and Vinyl Polysiloxane impression material- putty consistency (3M ESPE Express XT Putty Soft) was used to take impression of the arch that included the artificial crown. Impressions were poured using ELITE ORTHO type 3 dental stone (Zhermack) following manufacturer's instructions.

The dental casts were scanned using ortho insight 3D (Motion View, Micron Dental, Scottsdale, AZ 8528, USA) and the analysis for dimension between natural teeth and artificial crowns was performed on the same software.

A Boley gauge (Premium Instruments 16 Henry Ave, Ronkonkoma New York, 11779 USA, phone number 631-747-0656) was used to measure the bucco-lingual and mesio-distal dimensions of the involved teeth on the dental casts. The widest point equivalent to the maximum bulbosity of the crowns was measured at the mid-point with the Boley gauge and the digital method. The Mesio-Distal dimension was measured from marginal to marginal ridge.

The data were analyzed by using SPSS version 20.0 statistical package program. The mean of the crown dimension will be compared using Paired Student's t test to assess the significance of the difference between gingival bleeding on the artificially crowned teeth and their contralateral natural teeth. Chi square tests was applied on categorical data and the level of significant was set at $P < 0.05$.

5. RESULTS

A total of 16 patients with 20 pairs of crowns were examined. Thus 4 patients had 4 pairs of natural and artificial crowns. Overall a sample of artificial crowns including their contralateral natural teeth in 16 patients were included in this study.

Table 1. Mean age by gender

	Gender	N	Mean	Std. Deviation
Age in years	Male	11	43.1	8.2
	Female	5	44.8	9.8

The mean age and standard deviation of the participants by gender is shown in table 1. The sample consisted of 11 males and 5 females. There was no statistical difference in age by gender.

Table 2. Number of years in service of artificial crowns

Years in service	Frequency	Percent
0-2 years	11	55%
2-5 years	7	35%
5-10 years	1	5%
> 10 years	1	5%
Total	20	100%

Most of the crowns (55%) were in service for less than 2 years as shown in table 2.

Table 3. Position of artificial crown

Tooth number (FDI)	Frequency	Percent
16	2	10%
17	2	10%
26	6	30%
27	1	5%
36	3	15%
37	3	15%
46	1	5%
47	2	10%
Total	20	100%

Table 3 Shows that upper left first molar was the most frequently crowned tooth (6 crowns) in this sample, while the upper left second molar was the least crowned molar (1 crown).

Table 4. Crown material type

Crown material	Frequency	Percent
Metal	1	5%
Metal-ceramic	5	25%
All-ceramic	14	70%
Total	20	100%

All-ceramic crowns were the most fabricated crowns (14 crowns), with only one metal crown used to restore one tooth as shown in table 4.

Table 5. The relation between margin position and bleeding on probing on artificial crowns

		Bleeding on probing of artificial crown		Total
		No	Yes	
Margin position	Sub-gingival	2	4	6
	Supra-gingival	4	10	14
Total		6	14	20

Chi square= 0.045, $p > 0.05$, not statistically significant

Bleeding on probing was present adjacent to 14 out of 20 artificial crowns. Artificial crowns with supra-gingival margins had more bleeding on probing (71%) compared to crowns with sub-gingival margins (66%). The difference in bleeding on probing between sub-gingival and supra-gingival groups was not statistically significant.

Table 6. The relation between margin position and Basic Periodontal Examination on artificial crowns

		BPE on artificial crown			Total
		2	3	4	
Margin position	Sub-gingival	1	5	0	6
	Supra-gingival	2	9	3	14
Total		3	14	3	20

The Basic Periodontal Examination code 3 was the most frequent code for sub-gingival and supra-gingival groups. The different frequencies for Basic Periodontal Examination between sub-gingival and supra-gingival groups was not statistically significant.

Table 7. The relation between Basic Periodontal Examination on natural teeth and artificial crowns

		Natural BPE			Total
		2	3	4	
Artificial BPE	2	3	0	0	3
	3	8	5	1	14
	4	0	3	0	3
Total		11	8	1	20

Spearman Correlation = 0.5, $P < 0.05$.

Table 7 shows that periodontal status was modestly correlated within the group of patients meaning that patients had a poor periodontal status for both their natural and artificial crowned teeth.

Table 8. The relation between bleeding on probing on natural teeth and artificial crowns

		Natural BOP		Total
		No	yes	
Artificial BOP	No	3	3	6
	Yes	3	11	14
Total		6	14	20

Spearman Correlation = 0.2, $P > 0.05$.

Table 8 shows the frequency distribution of bleeding on probing between natural teeth and artificial crowns. There was no association between bleeding on probing around artificial crowns compared to gums adjacent to natural teeth.

Table 9. Bucco-lingual dimension of natural teeth and artificial crowns

		Mean	N	S.D	Sig.
Pair 1	Artificial BL (gauge) mm	11.57	20	1.03	0.019
	Natural BL (gauge) mm	11.17	20	0.95	
Pair 2	Artificial BL (digital) mm	11.49	20	0.99	0.014
	Natural BL (digital) mm	11.07	20	1.03	

The mean bucco-lingual dimensions of artificial crown and natural teeth using the digital scanner and Boley gauge are shown in table 9. Artificial crowns had a significantly greater mean bucco-lingual dimension compared to their natural counterparts ($P<0.05$) as measured by both methods using paired T- student test.

Table 10. Mesio-distal dimension of natural teeth and artificial crowns

		Mean	N	S.D	Sig.
Pair 1	Artificial MD (gauge) mm	10.32	20	0.89	NSS
	Natural MD (gauge) mm	10.26	20	0.77	
Pair 2	Artificial MD (digital) mm	10.24	20	0.87	NSS
	Natural MD (digital) mm	10.16	20	0.77	

The mean mesio-distal dimension of artificial crowns and natural teeth is shown in table 11. There was no statistical difference using either method of measurement.

Table 11. Type of occlusal scheme of artificial crown and natural teeth with their opposing teeth

		Natural occlusal scheme			Total
		Cusp to fossa	Cusp to cusp	Cross-bite	
Artificial occlusal scheme	Cusp to fossa	14	0	0	14
	Cusp to cusp	2	0	1	3
	Cross-bite	1	1	1	3
Total		17	1	2	20

Spearman Correlation = 0.6, $P < 0.05$.

The occlusal scheme is shown in table 11. A cusp tip to fossa relatively was the most prevalent occlusal scheme with a modest correlation between artificial crowns and contralateral sound teeth (Spearman rho= +0.6, $P < 0.05$).

Table 12. Degree of contact tightness in ICP/CO for artificial crowns

	Frequency	Percent
Tight contact	11	55%
Loose contact	6	30%
No contact	3	15%
Total	20	100%

Table 13. Degree of contact tightness in ICP/CO for natural teeth

	Frequency	Percent
Tight contact	11	55%
Loose contact	7	35%
No contact	2	10%
Total	20	100%

There was no difference in inter-occlusal contact tightness of artificial crowns and natural teeth with their opposing teeth as shown in tables 12 and 13.

6. DISCUSSION

This study aimed to compare the dimension of artificial crowns with contralateral natural teeth. The periodontal status associated with natural teeth and crowned teeth was also assessed. The study was conducted on a convenience sample of 16 patients seen in Dubai Dental Clinic. Each patient had at least a single artificial crown which was measured and compared to the contralateral natural tooth.

The bucco-lingual dimension of artificial crowns was significantly greater than contralateral natural teeth. The mean difference was 0.39 mm using a Boley gauge and 0.41 mm using an extra-oral digital scanner. The mean mesio-distal dimension of natural teeth and artificial crowns was not different. Previous studies found that the bucco-lingual dimension on artificial crowns was significantly greater than on contralateral natural teeth.[17,19,21] Parkinson found that porcelain fused to metal crowns were on average 0.71 mm wider than contralateral natural teeth and full metal crowns were 0.36 mm wider.[17] A similar observation was also found by Ehrlich as the mean bucco-lingual dimension of maxillary posterior artificial crowns increased from 9.46 mm to 10.44 mm after restoration while the mean increase for mandibular posterior artificial crowns was from 8.01 mm to 8.76 mm.[19] On the other hand, Alhouri found that 70% of artificial crowns had similar dimension to natural teeth, 13% were over-contoured, and 17% were under-contoured.[21]

The effect of artificial crowns on periodontal status was assessed by bleeding on probing and periodontal pocket depth. There was no significant difference in bleeding on probing and periodontal pocket depth between artificial crowns and natural teeth in this study. Several factors can be associated with the difference in periodontal status between artificial crowns and natural teeth such as the dimension of the artificial crowns and its possible interference with oral hygiene measures. The position and integrity of the crown margin and the presence of rough surfaces acting as plaque retentive factor. Previous studies comparing periodontal status between artificial crowns and natural teeth had conflicting results. Similar to the result of this

study, there was no significance difference in periodontal status between over-contoured artificial crowns and natural teeth.[25,28] Unlike the current results, bleeding on probing was associated with over-contoured surfaces compared to under-contoured surfaces.[9] Similarly, 59% of over-contoured mandibular and 70% of maxillary over-contoured crowns were associated with gingival inflammation. [24]

Several studies compared periodontal health between artificial crowns and natural teeth without stating the position of the crown margin nor crown dimension. For example, periodontal health was significantly worse around artificial crowns when compared to natural teeth in 78 females.[35] On the other hand, there was no difference in pocket probing depth, clinical attachment level and bleeding on probing between crowned teeth and contralateral natural teeth but surprisingly, plaque index was higher around natural teeth compared to crowned teeth.[36] Periodontal status around natural teeth was worse compared to crowned teeth.[51] Although visible plaque around crowned teeth was significantly less than around natural teeth. Despite this strange result, gingival bleeding index and probing pocket depth were significantly higher on crowned teeth compared to control teeth. Similar results raise the question of whether patients have more awareness while performing oral hygiene measures (brushing) on artificial crowns more than their natural teeth.

The relation between periodontal health and crown margin position is a heavily studied topic in the field of periodontics and prosthodontics.[37-57] In this study, supra-gingival crown margins were present in 14 crowns and 6 crowns had sub-gingival crown margins. The position of crown margin at the time of restoration is not known. Clinical attachment loss after crown placement may convert a sub-gingival margin to be a supra-gingival margin. The change in margin position over time has been reported in the literature.[44] Sub-gingival margin may became supra-gingival with recession with the percentage of sub-gingival margins having decreased from 65% to 41% after 5 years due to clinical attachment loss converting them to supra-gingival margins.

In this study, there was no significant difference in bleeding on probing and periodontal pocket depth between supra-gingival and sub-gingival groups. A similar observation was seen in a study that included 12 gold crowns with half of the facial margin placed supra-gingival and the other half placed sub-gingivally. Marginal integrity was considered a more important factor than position of the margin as a requirement for healthier periodontal tissue.[41]

The difference in periodontal health between supra-gingival and sub-gingival crown margins was also not statistically significant in a sample of 432 crowns. But when comparing artificial crowns to natural teeth, mean plaque score was significantly greater on sub-gingival margins group.[46] Similarly, other studies associated sub-gingival margins with significantly more periodontal inflammation compared to natural teeth or supra-gingival margins.[39,47,52] conversely, more plaque and gingivitis with supra-gingival crown margins compared to sub-gingival crown margins has also been reported in the literature.[49,37]

The effect of crown material on crown dimension can be related to the discrepancy between amount of tooth reduction during preparation and the required thickness of the restorative material,[2-4] and the smoothness of crown surfaces and it's possible role as a plaque retentive factor.[72] When it comes to the impact on periodontal tissues, it's very difficult to relate the impact to the material type only as several factors can have an impact such as margin position, crown contour, finishing and polishing of the crown surfaces and oral hygiene of the patient.

The role of crown material on periodontal health cannot be evaluated in this study due to the issue of confounding factors, small number of crowns from each crown material (14 all ceramic crowns, 5 porcelain fused to metal, and 1 metal crown), and the fact that the length of service is different between the crowns.

Several studies in the literature evaluated the effect of crown material on periodontal status. Some studies reported greater plaque scores on type III gold compared to porcelain.[58,61] Cast gold had higher bacterial adhesion compared to porcelain,[64] whilst others did not find a statistical difference between acrylic, gold and porcelain in terms of bacterial count.[60] No

difference in plaque and gingival indices, and pocket depth was found between zirconia and metal ceramic.[66]

The difference in occlusal scheme and centric contact was not statistically significant between artificial crowns and natural teeth which may indicate the attempts of the laboratory technicians to match artificial crowns to natural teeth.

This study concluded that artificial crowns are significantly wider bucco-lingually than their contralateral natural teeth. There was no difference in periodontal health around natural teeth and artificial crowns.

Several limitations are present in this study such as small sample size particularly with only one metal crown and the lack of information about the margin location at the time of restoration. The oral hygiene protocol followed by the patient was not recorded and most of the artificial crowns were in service for two years or less.

7. CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

- Bucco-lingual dimension of artificial crowns was significantly greater than the bucco-lingual dimension of natural teeth.
- The difference in mesio-distal dimension of artificial crowns was not significantly different compared to natural teeth.
- Periodontal status around artificial crowns were not significantly different than natural teeth despite the greater bucco-lingual dimension.
- The periodontal status was modesty correlated within the group, no significant difference between artificial crowns and natural teeth in the same patient.
- Smoking was not considered in the study
- The occlusal scheme and occlusal contacts were not significantly different on artificial crowns compared to their natural counterparts, which may indicate that laboratory technicians were matching the artificial crowns to the contralateral natural teeth.
- Under-preparation by dentists will also lead to bulbous over-contoured artificial crowns because technicians lack space for restorative materials.

8. REFERENCES

1. Dawson P. Posterior occlusion. In: Functional occlusion from TMJ to smile design. Elsevier; 2007:207-233.
2. Rosenstiel S, Land M, Fujimoto J. The complete cast crown preparation. In: Contemporary Fixed Prosthodontics (FIFTH EDITION). Elsevier; 2016:211.
3. Rosenstiel S, Land M, Fujimoto J. The metal-ceramic crown preparation. In: Contemporary Fixed Prosthodontics (FIFTH EDITION). Elsevier; 2016:227.
4. Rosenstiel S, Land M, Fujimoto J. Tooth preparation for all-ceramic restorations. In: Contemporary Fixed Prosthodontics (FIFTH EDITION). Elsevier; 2016:267.
5. Vasconcelos F, Neves A, Silva-Concílio L, Cunha L. Influence of anatomic reference on the buccal contour of prosthetic crowns. Brazilian Oral Research. 2009;23(3):230-235.
6. Petridis H, Tsiggos N, Michail A, Kafantaris S, Hatzikyriakos A, Kafantaris N. Three-dimensional positional changes of teeth adjacent to posterior edentulous spaces in relation to age at time of tooth loss and elapsed time. The European Journal of Prosthodontics and Restorative Dentistry. 2010;18(2):78-83.
7. Wheeler R. Some fundamentals in tooth form. Dental Cosmos. 1928;70:889.
8. Wheeler R. Restoration of gingival or cervical margins in full crowns. Dental Cosmos. 1931;73:238.
9. Perel M. Axial crown contours. The Journal of Prosthetic Dentistry. 1971;25(6):642-649.
10. Koivumaa K, Wennstorm A. A histologic investigation of the changes in gingival margins adjacent to gold crowns. Odontologisk Tidskrift. 1960;68:373.
11. Herlands R, Lucca J, Morris H. forms, contours and extensions of full coverage restorations in occlusal reconstructions. Dental Clinics of North America. 1962;6:147.

12. Yuodelis R, Weaver J, Sapkos S. Facial and lingual contours of artificial complete crown restorations and their effects on the periodontium. The Journal of Prosthetic Dentistry. 1973;29(1):61-66.

13. Löe H, Theilade E, Jensen S. Experimental gingivitis in man. Journal of Periodontology. 1965;36(3):177-187.

14. Morris M. Artificial crown contours and gingival health. The Journal of Prosthetic Dentistry. 1962;12(6):1146-1156.

15. Lindhe J, Wicén P. The effects on the gingivae of chewing fibrous foods. Journal of Periodontal Research. 1969;4(3):193-200.

16. Burch J. Ten rules for developing crown contours in restorations. Dental clinics of North America. 1971;15(3):611-618.

17. Parkinson C. Excessive crown contours facilitate endemic plaque niches. The Journal of Prosthetic Dentistry. 1976;35(4):424-429.

18. Wagman S. The role of coronal contour in gingival health. The Journal of Prosthetic Dentistry. 1977;37(3):280-287.

19. Ehrlich J, Yaffe A, Weisgold A. Faciolingual width before and after tooth restoration: a comparative study. The Journal of Prosthetic Dentistry. 1981;46(2):153-156.

20. Meijering A, Peters M, DeLong R, Pintado M, Creugers N. Dimensional changes during veneering procedures on discoloured teeth. Journal of Dentistry. 1998;26(7):569-576.

21. Alhouri N, Watts D, McCord J, Smith P. Mathematical analysis of tooth and restoration contour using image analysis. Dental Materials. 2004;20(9):893-899.

22. Ash M, Gitlin B, Smith W. Correlation between plaque and gingivitis. Journal of Periodontology. 1964;35(5):424-429.

23. Hazen S, Asborne J. Relationship of operative dentistry to periodontal health. Dental Clinic of North America. 1967;11:245-254.

24. Sackett B, Gildenhuys R. The effect of axial crown overcontour on adolescents. Journal of Periodontology. 1976;47(6):320-323.

25. Ehrlich J, Hochman N. Alterations on crown contour effect on gingival health in man. The Journal of Prosthetic Dentistry. 1980;44(5):523-525.

26. Creugers N, Snoek P, Vogels A. Overcontouring in resin-bonded prostheses: plaque accumulation and gingival health. The Journal of Prosthetic Dentistry. 1988;59(1):17-21.

27. Sundh B, Köhler B. An in vivo study of the impact of different emergence profiles of procera titanium crowns on quantity and quality of plaque. The International Journal of Prosthodontics. 15(5):457-460.

28. Kohal R, Gerds T, Strub J. Effect of different crown contours on periodontal health in dogs. Clinical results. Journal of Dentistry. 2003;31(6):407-413.

29. Kohal R, Pelz K, Strub J. Effect of different crown contours on periodontal health in dogs. Microbiological results. Journal of Dentistry. 2004;32(2):153-159.

30. Mahajan M. histological evaluation of gingiva in complete crown restorations [Dissertation]. Loyola University Dental School of Chicago. 1976.

31. Jameson L. Comparison of the volume of crevicular fluid from restored and nonrestored teeth [Dissertation]. Loyola University Dental School of Chicago. 1979.

32. Koth D. Full crown restorations and gingival inflammation in a controlled population. The Journal of Prosthetic Dentistry. 1982;48(6):681-685.

33. Al-Wahadni A, Mansour Y, Khader Y. Periodontal response to all-ceramic crowns (IPS Empress) in general practice. International Journal of Dental Hygiene. 2006;4(1):41-46.

34. Ababnaeh K, Al-Omari M, Alawneh T. The effect of dental restoration type and material on periodontal health. Oral health & Preventive Dentistry. 2011;9(4):395-403.

35. Al-Sinaidi A, Preethanath R. The effect of fixed partial dentures on periodontal status

of abutment teeth. The Saudi Journal for Dental Research. 2014;5(2):104-108.

36. Juárez I, Larroulet S, Ojeda M, Rosas C. Periodontal status of teeth restored with crowns and its contralateral homologue, Valdivia- Chile. Journal Of Oral Research. 2015;4(3):167-173.

37. Marcum J. The effect of crown marginal depth upon gingival tissue. The Journal of Prosthetic Dentistry. 1967;17(5):479-487.

38. Silness J. Periodontal conditions in patients treated with dental bridges. Journal of Periodontal Research. 1970;5(1):60-68.

39. Silness J. Periodontal conditions in patients treated with dental bridges. 2. The influence of full and partial crowns on plaque accumulation, development of gingivitis and pocket formation. Journal of Periodontal Research. 1970;5(3):219-224.

40. Karlsen K. Gingival reactions to dental restorations. Acta Odontologica Scandinavica. 1970;28(6):895-904.

41. Richter W, Ueno H. Relationship of crown margin placement to gingival inflammation. The Journal of Prosthetic Dentistry. 1973;30(2):156-161.

42. Newcomb G. The relationship between the location of subgingival crown margins and gingival inflammation. Journal of Periodontology. 1974;45(3):151-154.

43. Larato D. Effects of artifical crown margin extension and tooth brushing frequency on gingival pocket depth. The Journal of Prosthetic Dentistry. 1975;34(6):640-643.

44. Valderhaug J, Birkeland J. Periodontal conditions in patients 5 years following insertion of fixed prostheses. Pocket depth and loss of attachment. Journal of Oral Rehabilitation. 1976;3(3):237-243.

45. Müller H. The effect of artificial crown margins at the gingival margin on the periodontal conditions in a group of periodontally supervised patients treated with fixed bridges. Journal of Clinical Periodontology. 1986;13(2):97-102.

46. Orkin D, Reddy J, Bradshaw D. The relationship of the position of crown margins to gingival health. The Journal of Prosthetic Dentistry. 1987;57(4):421-424.

47. Flores-de-Jacoby L, Zafiropoulos G, Ciancio S. Effect of crown margin location on plaque and periodontal health. The International Journal of Periodontics & Restorative Dentistry. 1989;9(3):197-205.

48. Felton D, Kanoy B, Bayne S, Wirthman G. Effect of in vivo crown margin discrepancies on periodontal health. The Journal of Prosthetic Dentistry. 1991;65(3):357-364.

49. Freilich M, Niekrash C, Katz R, Simonsen R. Periodontal effects of fixed partial denture retainer margins: configuration and location. The Journal of Prosthetic Dentistry. 1992;67(2):184-190.

50. Valderhaug J, Ellingsen J, Jokstad A. Oral hygiene, periodontal conditions and carious lesions in patients treated with dental bridges. A 15-year clinical and radiographic follow-up study. Journal of Clinical Periodontology. 1993;20(7):482-489.

51. Giollo M, Valle P, Gomes S, Rösing C. A retrospective clinical, radiographic and microbiological study of periodontal conditions of teeth with and without crowns. Brazilian Oral Research. 21(4):348-354.

52. Aboelsaad N, Mohammad R, Essam O, Badr S. An update on the effect of crown margin locations and materials on periodontal health. Egyptian Dental Journal. 2001;58(4):3639-3644.

53. Kancyper S, Koka S. The influence of intracrevicular crown margins on gingival health: Preliminary findings. The Journal of Prosthetic Dentistry. 2001;85(5):461-465.

54. Reitemeier B, Hänsel K, Walter M, Kastner C, Toutenburg H. Effect of posterior crown margin placement on gingival health. The Journal of Prosthetic Dentistry. 2002;87(2):167-172.

55. Abidi Y, Jameel A, Hasan, Rashid S. An evaluation of association between crown

margins & materials with the periodontal health. Journal of the Pakistan Dental Association. 2011;20(3):148-153.

56. Moretti L, Barros R, Costa P, Oliveira F, Ribeiro F, Novaes A, Palioto D. The influence of restorations and prosthetic crowns finishing lines on inflammatory levels after non-surgical periodontal therapy. Journal of the International Academy of Periodontology. 2011;13(3):65-72.

57. Paniz G, Nart J, Gobbato L, Chierico A, Lops D, Michalakis K. Periodontal response to two different subgingival restorative margin designs: a 12-month randomized clinical trial. Clinical Oral Investigations. 2016;20(6):1243-1252.

58. Wise M, Dykema R. The plaque-retaining capacity of four dental materials. The Journal of Prosthetic Dentistry. 1975;33(2):178-190.

59. Maruyama T, Simoosa T, Ojima H. Morphology of gingival capillaries adjacent to complete crowns. The Journal of Prosthetic Dentistry. 1976;35(2):179-184.

60. Ørstavik D, Arneberg P, Valderhaug J. Bacterial growth on dental restorative materials in mucosal contact. Acta Odontologica Scandinavica. 1981;39(5):267-274.

61. Chan C, Weber H. Plaque retention on teeth restored with full-ceramic crowns: a comparative study. The Journal of Prosthetic Dentistry. 1986;56(6):666-671.

62. Bader J, Rozier R, McFall W, Ramsey D. Effect of crown margins on periodontal conditions in regularly attending patients. The Journal of Prosthetic Dentistry. 1991;65(1):75-79.

63. Setz J, Diehl J. Gingival reaction on crowns with cast and sintered metal margins: a progressive report. The Journal of Prosthetic Dentistry. 1994;71(5):442-446.

64. Kawai K, Urano M. Adherence of plaque components to different restorative materials. Operative Dentistry. 26(4):396-400.

65. Weishaupt P, Bernimoulin J, Lange K, Rothe S, Naumann M, Hägewald S. Clinical and

inflammatory effects of galvano-ceramic and metal-ceramic crowns on periodontal tissues. Journal of Oral Rehabilitation. 2007;34(12):941-947.

66. Zenthöfer A, Ohlmann B, Rammelsberg P, Bömicke W. Performance of zirconia ceramic cantilever fixed dental prostheses: 3-Year results from a prospective, randomized, controlled pilot study. The Journal of Prosthetic Dentistry. 2015;114(1):34-39.

67. Naenni N, Bindl A, Sax C, Hämmerle C, Sailer I. A randomized controlled clinical trial of 3-unit posterior zirconia–ceramic fixed dental prostheses (FDP) with layered or pressed veneering ceramics: 3-year results. Journal of Dentistry. 2015;43(11):1365-1370.

68. Jalalian E, Mofrad G, Rahbar M, Mohseni A, Mohebbi M. In vitro adhesion of streptococcus mutans to polished IPS e.max and feldspathic porcelain. Journal of Islamic Dental Association of IRAN. 2015;27(4):182-185.

69. Wang Y, Cao Z, Zhan S. Effect of two kinds of porcelain crown on AST, ALP, TNF-α, IL-8, GP-x and MDA levels in gingival crevicular fluid. Journal of Hainan Medical University. 2016;22(17):153-156.

70. Ariaans K, Heussen N, Schiffer H, Wienert A, Plümäkers B, Rink L, Wolfart S. Use of molecular indicators of inflammation to assess the biocompatibility of all-ceramic restorations. Journal of Clinical Periodontology. 2016;43(2):173-179.

71. Hussein A, Hajwal S, Ab-Ghani Z. Bacterial adhesion on zirconia, lithium desilicated and gold crowns-in vivo study. Advances in Dentistry & Oral Health. 2016;1(5):555-574.

72. Jalalian E, Sarzaeem F, Pourchafjiri M. Adhesion of streptococcus mutans on glazed IPS e.max press, glazed feldspatic and dental enamel. Bioscience Biotechnology Research Communications. 2017;10(3):525-528.

73. Zlatanovska K, Dimova C, Zarkova-Atanasova J, Korunoska-Stevkovska V, Gigovski N, Kocovski D. Oral hygiene in patients with fixed prosthodontic restorations. Journal of Hygienic Engineering and Design, 2017;21:83-89.

74. Saravanakumar P, Padmanabhan T, Kumar, V, Mohamed K, Mani U, Grover M, Thangarajan S. Effect of different crown materials on the interLeukin-One Beta content of gingival crevicular fluid in endodontically treated molars: An original research. Cureus. 2017;9(6):e1361.

75. Stillman P. What is traumatic occlusion and how can it be diagnosed and corrected? The Journal of the American Dental Association (1922). 1925;12(11):1330-1338.

76. Glickman I, Weiss L. Role of trauma from occlusion in initiation of periodontal pocket formation in experimental animals. Journal of Periodontology. 1955;26(1):14-20.

77. Comar M, Kollar J, Gargiulo A. local irritation and occlusal trauma as co-factors in the periodontal disease process. Journal of Periodontology. 1969;40(4):193-200.

78. Stones H. An experimental investigation into the association of traumatic occlusion with parodontal disease: Journal of the Royal Society of Medicine. 1938;31(5):479-495.

79. Nunn M, Harrel S. The effect of occlusal discrepancies on periodontitis. I. Relationship of initial occlusal discrepancies to initial clinical parameters. Journal of Periodontology. 2001;72(4):485-494.

80. Harrel S, Nunn M. The effect of occlusal discrepancies on gingival width. Journal of Periodontology. 2004;75(1):98-105.

81. Reyes E, Hildebolt C, Langenwalter E, Miley D. Abfractions and attachment loss in teeth with premature contacts in centric relation: clinical observations. Journal of Periodontology. 2009;80(12):1955-1962.

82. Ishigaki S, Kurozumi T, Morishige E, Yatani H. Non-working contact does not initiate primary occlusal trauma. Prosthodontic Research & Practice. 2008;7:49-54.

83. Harrel S, Nunn M. The association of occlusal contacts with the presence of increased periodontal probing depth. Journal of Clinical Periodontology. 2009;36(12):1035-1042.

84. Zhou S, Mahmood H, Cao C, Jin L. Teeth under high occlusal force may reflect occlusal trauma-associated periodontal conditions in subjects with untreated chronic periodontitis. chinese Journal of Dental Research. 2017;20(1):19-26.

85. Popa C, Solomon S, Rudnic I, Martu I, Luchian L, Martu M, Sava N, Martu S. Evaluation of oclusal trauma as a risk factor in the ethiology of chronic periodontitis. International Journal of Medical Dentistry. 2018;8(2):83-88.

9. APPENDICES

Appendix 1: English consent form for participation in the study.

Consent form

I volunteer to participate in a research project conducted by Dr. Omar Bamedhaf from Mohammed Bin Rashid University of Medicine and Health Sciences under the supervision of Prof. Alex Milosevic. I understand that the project is designed to gather information for academic work.
My participation in this project is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without a penalty.
Participation involves being evaluated clinically by one examiner from Dubai Dental clinic. The evaluation will last approximately 10-15 minutes. An instrument will be used to measure the teeth dimensions, assess the gum condition and occlusion. An impression will be taken for your teeth to make a model that will be used for examination. Notes will be written during the evaluation.
I understand that the researcher will not identify me by name in any reports using information obtained from this research, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.
I understand that this research study has been reviewed and approved by research and ethical committee.
I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.
I have been given a copy of this consent form.

---	---
My signature	Date
---	---
My name	Signature of the researcher

Appendix 2: Arabic consent form for participation in the study.

الموافقة على المشاركة في بحث أكاديمي

اتطوع انا ..... للمشاركة في مشروع بحث يقوم به الطبيب المقيم عمر بامدهاف من جامعة محمد بن راشد للطب و العلوم الصحية تحت أشراف البروفوسير ألكس ميلوسفيتش.

أتفهم ان البحث مصمم للحصول على معلومات للعمل الاكاديمي.

مشاركتي في هذا البحث اختيارية من دون أي مقابل و يحق لي الانسحاب في اي وقت.

سوف تشمل المشاركة في هذا البحث عملية فحص بعض الاسنان و استخدام بعض الادوات لقياس حجم الاسنان و فحص اللثة. بالاضافة إلى القيام بأخذ مقاس للاسنان لعمل مثال دراسي.

سوف يقوم الطبيب المقيم عمر بامدهاف بعملية الفحص و جمع بعض المعلومات المتعقلة بحالة الاسنان و سوف يستغرق الفحص من 10-15 دقيقة.

جميع المعلومات ستأخذ بسرية تامة و لن يتم نشر معلوماتك الشخصية

تم قبول البحث من لجنة أخلاقيات الابحاث في جامعة محمد بن راشد للطب و العلوم الصحية

لقد تم منحي الوقت الكافي لقراءة و فهم الاحكام و الشروط و لقد قام الطبيب المقيم بالاجابة على كل استفساراتي.

اوافق على المشاركة الاختيارية في هذا البحث.

الاسم: ..... التاريخ:.....

التوقيع:..... توقيع الباحث:.....

Appendix 3: Data collection sheet

Data sheet

ID number ……. Age……. Gender……..

Smoking: Yes ☐ number of cigarettes per day …….
No ☐

Artificial crown on tooth (FDI number) ……

Opposing tooth: present Natural ☐ Artificial crown ☐ Missing ☐

Presence of neighbouring teeth: Artificial crown: Mesial only ☐ Distal only ☐
Both side ☐ None ☐

Crown type: metal crown: ☐
Metal-ceramic: ☐
Full ceramic: ☐

Number of years in service: 0-2 years ☐
2-5 years ☐
5-10 years ☐
More than 10 years ☐

Occlusal scheme	Cusp to fossa relationship	Cusp to cusp relationship	Cross-bite
On artificial crown			
On natural tooth			

Centric contact (Shimstock foil)	Tight contact	Loose contact	No contact
On artificial crown			
On natural tooth			

	Clinical evaluation							
Crown type (supra-gingival or sub-gingival)	Bleeding on probing	Bleeding on probing	Pocket depth of artificial crown (mm)			Pocket depth of natural tooth (mm)		
	Artificial	Natural	M	B	D	M	B	D
	Y/N	Y/N						
			M	L	D	M	L	D

Model analysis			
Measuring method	Measuring dimension	Artificial crown	Natural tooth
Gauge analysis	Buccal-lingual (mm)		
	Mesial- distal (mm)		
Digital scanner	Buccal-lingual (mm)		
	Mesial- distal (mm)		

Appendix 4: Approval letter from HBMCDM Research and Ethics Committee.

Date: 30/09/2017

Dear Dr Omar Bamedhaf

Re: Your research protocol

Titled: Comparison between the facio-lingual dimension and gingival status of artificial crowns and natural teeth

Thank you for submitting your research protocol to the Research and Ethics committee of the Hamdan Bin Mohammed College of Dental Medicine, MBRU.

It was considered at the meeting held on: 21st May 2017

My apologies for the late reply.

The committee had minor comments regarding the title, removal of "quantitative" as it is cross-sectional and the substitution of "periodontal" with "gingival". Since the original submission, you have this revised accordingly.

The study is now approved.

The committee would like to remind you that it is a requirement of the programme that you complete a research dissertation, which comprises 15% of credits within the 3-year MSc programme.

Wishing you every success with your study.

Yours sincerely,

Prof A Milosevic

Chair, Research and Ethics Committee, HBMCDM