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Evaluation of marginal and internal fit of Co-Cr copings by different manufacturing methods

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Abstract

Objective: The aim of this study was to determine the clinical acceptability of Co-Cr crown copings produced by 3 different techniques with compared the internal and marginal discrepancy.

Material and Methods: Sixty dental stone duplications of major die (processed upper molar) were examined and seperated into three. All Co-Cr copings were produced by milling, laser sintering and casting and milling methods in the form of twenty groups. At x180 magnification, marginal and internal gap of each coping was measured at 15 points on digital photographs. Data were analyzed using one-way analysis of variance (ANOVA) (α=0.05).

Results: The internal gap of the milling group was significantly larger than the conventional casting group ($p<0.05$). No significant difference was founded between marginal gaps of groups ($p>0.05$).

Conclusion: Within the limitations of this in vitro study, Co-Cr copings from milling indicated larger internal gap values than copings from conventional casting. All copings were showed clinically acceptable marginal and internal gap. all techniques were clinically accepted for the fabrication of Co-Cr copings.

Keywords: Computer-aided design, Dental marginal adaptation, Dental crown

Introduction

CAD (computer aided design)/CAM (computer aided manufacturing) system is a useful part of dentistry where restorations are fabricated with computer aid.[1] The advantage of the CAM/CAD system is that it provides many alternatives to traditional impression and manufacturing techniques. In this way, different materials which are not used by traditional methods are also used.[1, 2]

Metal ceramic restorations are frequently used in dentistry. They are often preferred in the posterior regions of the jaws where high forces are loading on the teeth. They have satisfactory and long survive.[3] The traditional technique used to fabricate metal coping is the loss-wax casting technique method, which has the disadvantages that include distortion of wax patterns, inconsistencies in the casting metal, complex procedures and time-consuming processing.[4,5]

Recently, CAD/CAM milling and DMLS (direct metal laser sintering) manufacturing systems have been used due to the disadvantages of casting technique in the fabrication of coping. In CAD/CAM milling system, a special software is designed; then fabrication is done with CAM.[6]

Dental casting alloys can be divided into noble alloys such as nickel-chromium (Ni-Cr) and Cobalt-chromium (Co-Cr) alloys and base metal alloys.[7-10] Co-Cr alloy is commonly used in the manufacture of metal frameworks, due to the fact that its biocompatibility is less expensive than gold and allergic reactions are associated with Ni-Cr alloy.[9, 11] However, due to the high degree of melting of Co-Cr casting alloy, it must be heated to high temperatures before casting. This is difficult to provide in the dental laboratory.[7] The development of CAD/CAM procedures initiated automated manufacturing processes.[9, 10, 12, 13] CAM milling, based on subtractive manufacturing, was introduced to the market for the fabrication of dental restorations along with the conventional casting technique.[9, 10, 12, 14]

Good marginal fit is an important factor in the long-term success of partial fixed dental prostheses (FDPs), because it minimizes plaque deposition, the repetitive caries and periodontal problems. The accuracy of restorations made with CAD/CAM technology may not be as consistent as in dental prosthesis manufacturing processes such as casting.[10] However, restricted information is available on the marginal difference of alloys manufactured with new production techniques.[15]

The spacing on the axial walls of tooth affects the restoration retention negatively and may cause the restoration to break. Furthermore, the gap in the axial walls of tooth causes microorganisms or toxins to infiltrate into the tooth axial walls. They get at the pulp through the dentin tubulus and cause pulp irritation.[16]

There isn't any agreement among the researchers on the criteria for the adaptation of restorations. The best fit criterion is defined as the misfit of the different points measured between the prepation surface and the restoration inner surface. Measurements between restoration and tooth to determine the adaptation of restoration; can be made on the inner surface, at the edge or at the points on the outer surface of the restoration. (Fig. 2).[17]

Although metal-ceramic crowns are widely used clinically, they are usually produced by Ni-Cr alloys from the casting process, and this is the subject of many studies.[18-20] Few studies have made a comparative evaluation of the compatibility of marginal and internal metal copings from Co-Cr alloys. Therefore, in this study, Co-Cr alloy copings for metal-ceramics are CAD/CAM milling, DMLS and casting.

Comparative samples were fabricated by using traditional lost wax technique to determine to what extent marginal gap vary according to the fabrication method and whether these discrepancies are within the clinical acceptance gap. The aim of this study was to determine the clinical acceptability of crown copings produced by 3 different techniques. The null hypothesis is that ''internal and marginal gaps of the copings fabricated with different manufacturing techniques will be the same''.

Material and Methods

A resin tooth of a maxillar right first molar in a typodont model (frasaco-frasaco GmbH, Tettnang, Germany) was prepared for full covarage crown according to preparation rules. We selected this tooth as metal-ceramic restorations are still a very preferred option to the posterior regions. In the tooth preparation, a chamfer with a rounded internal angle of 1-mm-wide was made in the cervical region of the tooth. All sharp edges were rounded during tooth preparation. The prepared acrylic tooth was scanned with a laboratory scanner. Master metallic die was fabricated with laser sintering system.

The fabricated master die was placed in a 4-cm-diameter open top aluminum tube and was duplicated with vinylpolysiloxane duplication silicone (Elite Double 32 Fast, Zhermack GmbH, Badia Polesine (RO), Italy) and fabricated silicone guide. The silicone guide was dublicated sixty times with type-4 CAD/CAM dental stone (Rocky Mountain, Klasse4 Dental, Parkstetten, Germany). Sixty dental stone dies were fabricated and divided into 6 groups. Each group was scanned with laboratory scanner (Yenascan E7-Yenadent Ltd. Sti., Istanbul, Turkey). The virtual designs of the copings were made by a single operator using software (exocad V 2.2, exocad GmbH, Darmstadt, Germany). The thickness of the coping was set to 0.5 mm and the cement space was set to 35µm. Twenty CAD/CAM milling Co-Cr copings (CMC) were fabricated from prefabric Co-Cr block (Starbond Cr-Co Easy Disc, S&S Scheftner GmbH, Mainz, Germany) using 5-axis milling machine (Yenadent D40-Yenadent Ltd. Sti., Istanbul, Turkey). DMLS Co-Cr copings (LSC) were fabricated from the Co-Cr powder (Remanium® star CL, Dentaurum GmbH & Co. KG, Ispringen, Germany) with laser sintering system (Concept Laser Mlab cusing 200R-Concept Laser GmbH, Lichtenfels, Germany). The designed casting copings (CC) were milled from wax block (Calibration, Yenadent Ltd. Sti., Istanbul, Turkey) and fabricated with conventional cast method using Co-Cr powder (Scheftner Starbond Cos 30, S&S Scheftner GmbH, Mainz, Germany).

Each produced copings was cemented to its own stone die with dual-cure resin cement (NOVA Resin Cement, Imıcrly, Konya, Turkey). The fabricated copings were cemented with a force of approximately 50 N (5kg) was applied onto occlusal central fossa and waited for 5 minutes and excess cement was removed (Fig. 1a).

Cemented specimens were placed into the specially prepared silicone pattern in the appropriate position and embedded in the acrylic (Meliodent, Kulzer GmbH, Hanau, Germany) to prevent decementation during cutting processes. The silicone pattern was specifically designed to ensure that the specimens were in the same position and the incision line was in the same location (Fig. 1b). Embedded specimens were cut mezio-distally with precision cutting machine (MKC-100-Mod Dental, Esetron Mekatronik Müh. San. Tic. Ltd. Şti., Ankara, Turkey) (Fig. 1c,d), then these were polished with 1500 and 2000 grit of sandpaper respectively. For the standardization of marking the measurement points, reference was taken from the axio-occlusal angle. 1-mm-spacing in the occlusal, 1.5-mm spacing in the axial markings were made with a pencil.

Adaptation of copings was observed and photographed digitally with 20.2 megapixel camera (Canon 70D-Canon, Tokyo, Japan) integrated video microscope (Lapsun-Lapsuntech, Hongkong, China) at x180 magnification (Fig. 1e). Digital photographies (5427x3648 resolution) were taken as raw format with precision stage micrometer (0,01mm) for measuring the calibration. Marginal and internal gap were measured at 15 measurement points defined by Holmes et al. in 6 standardized areas (Fig. 2). Five measurements were made for each points and averaged. Therefore, 75 measurements were made in each sample and 4500 measurements in total. All measurements were made in special software (Image J 1.52a, Wayne Rasband, NIH, USA) (Fig. 3).

The measuring points shown in the Figure 4 were evaluated for accuracy of coping fit. Statistical analysis was performed with SPSS program (version 22 SPSS, Chicago. IL, USA). Descriptive statistical methods (mean, standard deviation=SD) were used to evaluate the data, and post hoc (Tukey and Bonferroni) analyses and one-way ANOVA were used for comparison of multiple groups. The results were evaluated at $p<0.05$ significance level.

Results

Average values and standart deviations (SD) of marginal and internal gap for all groups are shown in Table 1. Overall average gap value was 137.40±94.02 µm for CMC, 90.41±75.32 µm for LSC and 101.84± 60.09 µm for CC group (F=36.123). Average internal gap was 144.49±104.27 µm for CMC, 94.30±76.15 µm for LSC and 105.64±60.22 µm for CC group (F=26.941). There was statistical difference between the milling and casting groups. LSC group had the less values and discrepancies.

Marginal gap value was 91.32±49.47 µm for CMC, 65.11±77.169 µm for LSC and 77.16±53.70 µm for CC (F= 2.158). Average values for internal regions were found as follows. CSG found 132.97 ±50.91 µm for CMC, 90.79±81.72 µm for LSC and 92.96±51.82 µm for CC (F=5.663). AWG found 72.16±32.23 µm for CMC, 47.4 ±19.68 µm for LSC and 61.57± 24.41 µm for CC (F=18.226). AOG found 71.55±40.98 µm for CMC, 90.56±39.72 µm for LSC and 98.04±30.81 µm for CC (F=5,319).OG found 197.88±77.39 µm for CMC, 158.85±80.05 µm for LSC and 173.44±60.34 µm for CC (F=4.363) and there wasn't any statistical difference between the groups. CAG found 293.50±69.94 µm for CMC, 98.41 ± 93.90 µm for LSC and 112.36±49.04 µm for CC (F=88.198) and there was statistical difference between the milling and casting groups. The null hypothesis was rejected.

Discussion

There are many different measurement techniques for determining marginal and internal adaptation. [21, 22] In the studies, direct and cross-sectional examination methods were used widely.[23-27]

The preparation of the tooth according to certain principles is important in terms of the conservation of the restoration and the distribution of the forces coming to the support tooth. In many studies, the adaptation of the copings with the model was achieved by finger pressure (8±1.3 kg).[20, 28, 29] In the literature studies; cementation was carried out by applying a force of 50 N (~5 kg) to maintain dimensional stability while cementing.[30, 31] Achieving healthier results is possible by increasing the measurement points and numbers and decreasing the standard deviation. In vitro studies have been reported that 50 measurement is ideal for the determination of marginal fit and at least 20-25 measurements should be performed.[32] While some researchers evaluated the restoration fit in points, others divided the measurement points into regional groups and made evaluations on these regions.[28, 33, 34] Different numbers of samples were used in the researches in which the accuracy of crowns were examined.[17, 35] We obtained cross-section mesio-distal direction from the same point of the samples under digital video microscope and divided these 15 points into 6 regions and made evaluation regionally.The results are aimed to be more reliable with a great number of samples and measurements.

Foster emphasized that clinically misfit marginal gap is one of the technical issues leading to failure.[36] According to Levine, the theoretical marginal thickness of the cement should be 20-40 µm for the ideal marginal fit.[37, 38] But this is clinically difficult to achieve. May et al. suggested that the marginal gap should be between 25-40 µm after cementation but it is very rare to provide this clinically.[39] McLean and Franunhofer examined over 1000 restorations in 5 years and stated that the acceptable clinical value was at most 120 µm.[40]

Christensen stated that the acceptable value for clinical subgingival margin gap was 34-119 µm and for supragingival gap was 2-51 µm.[41] Some researchers have indicated that the clinical margin gap of 100-150 µm is sufficient.[42, 43] However; Hunter, Good and many other researchers have suggested that the clinical margin gap of 200 µm is sufficient.[32, 44-48] In our study, good marginal gap between crown copings made with three different systems was observed in DMLS system with an average of 65.11 µm and the highest marginal gap was found in milled samples with an average of 91.32 µm. Our measurement values did not reach the value of 120 µm which is the critical point for the marginal gap value of all group averages and are clinically acceptable methods.

Adaptation process of produced coping increases the settlement of the restoration and reduces the internal and marginal gap. Witkowski et al. have examined the horizontal and vertical fitting of the titanium copings fabricated with the CAD/CAM system to determine the effect of pre-and post-adaptation on marginal fit. The marginal gap was 32.9 µm-127.8 µm before adaptation and 3.4 µm-58.4 µm after adaptation. This study reported that the adaptation to the copings obtained with CAD/CAM technology reduced the marginal gap significantly.[49] Adaptation process was not performed in our study to maintain standardization. If the adaptation process had been done, marginal and internal gap could have been less.

Shokry et al. have made measurements of titanium and Ni-Cr single crowns before and after the porcelain firing.The copings are produced from pure titanium material with Everest system and evaluated the average marginal gap after opaque and dentin application. These values are as follows; 24.1 µm in the copings, 32.3 µm after opaque application and 35.6 µm after dentin application. The values of pure titanium obtained by casting technique are as follows; 81.5 µm in the coping, 83.8 µm after opaque application and 83.7 µm after dentin application. In the Ti-6Al-7Nb copings fabricated with casting technique, these values are as follows; 47.3 µm in the coping, 70.6 µm after opaque application and 70.6 µm after dentin application. In Ni-Cr copings obtained by casting technique, these values are as follows; 92.8 µm in copings, 97.9 µm after opaque application and 94 µm after dentin application. More marginal discrepancies have been identified in Ni-Cr frameworks.[50] Xu et al., examined the marginal and internal fit of single unit metal frameworks in vitro. They found the marginal fit of selective laser melting and Co-Cr framework to be 102.86 m for selective laser melting and 170.19 m for casting.[51]

Park et al. founded the average marginal gap of single-unit metal frameworks were 36.96 µm in the casting group, 63.21 µm in the CAM/CAD group (Datron D5) and 70.98 µm in the DMLS (Eosint M270) group.[52] Looking at the marginal adaptation studies of 3 unit metal frameworks fabricated with CAM/CAD, laser sintering and casting technique; Ortorp et al. in their in vitro study, the 3-unit Co-Cr FDPs frameworks marginal gap values; DMLS group: 84 µm, wax milling group: 117 µm, casting group: 133 µm and CAM/CAD metal group: 166 µm were found. The best marginal gap value found to the DMLS group with 84 µm.[53] Kim et al. founded, the average marginal gap values of 3-unit crowns were 130.6 µm for premolars in the DMLS (Eosint M270) group, 133.1 µm for premolars, and 81.7 µm for premolars in the cast group (Ni-Cr). They measured 81.8 µm for molars.[54] Nesse et al. made the direct comparison and scoring technique of casting, 3-unit Co-Cr frameworks and suggested that CAM / CAD technique is better than laser sintering and traditional casting technique.[10] Uçar et al. investigated the internal fit of single crowns fabricated with DMLS and traditional casting method. As a result of the research;

internal fit was 58.21 μm for Co-Cr crowns and 50.55 μm for Ni-Cr crowns produced with casting method and 62.57 μm for DMLS crowns and no statistically significant difference was found.[20]

Yeo et al. have examined the traditional In-Ceram, Celay In-Ceram, IPS Empress-2 full ceramic crowns and metal ceramic crowns as a control group. They revealed the mean marginal gap of 87 μm in porcelain firing measurements in metal ceramic crowns.[27] The lack of porcelain firing is the missing aspect of our study. If this is done, marginal and internal range values may decrease.

In the studies where fixed prosthetic restorations were examined in the marginal and internal gaps, different values were found due to the existence of many reasons from the measurement techniques to the materials used. It is stated in the literature whether the research is in vivo or in vitro, the number of samples, the measurement technique and the number of studies lead to the difference between studies.[55] Nawafleh et al. stated that the cementation of samples and the shape of the preparation affected marginal adaptation in addition to the other factors.[56] Marginal and internal adaptation of fabricated restoration with CAD/CAM system can be affected by many factors such as scanning of the model/tooth, designed software and the milling step.[57] Misfit may occur due to the drill size. Thus, it is essential for preparation to have round angles and flat walls.[5] We found the highest values in the milling group. The interval was significant especially in the chamfer and occlusal region. The difference in these regions can be due to the shape and diameter of the bur used. The high value in the chamfer angle region may be because of the 30^0 rotation angle of the milling machine A and B axis and the bur cannot rotate approximately convexity with 120^0 internal angle (Fig. 5a). In subtraction-based systems such as the CAD/CAM system, the diameter of the last drills milling the inner surface of the restoration may sometimes be larger than some surfaces of the prepare tooth, such as the margin. In this study, more internal range values can be obtained than the other production techniques.[58] According to the measurements, in all copings, the highest margin spacing values were observed in the occlusal region. Similar results were obtained in different studies and one of the reasons for this was said to be 'total occlusal convergence - TOC'.[59] TOC was 10^0 in this study and we found similar results. Higher fit in the axio occlusal area is in the milling group because the axial-occlusal angle is compatible with the diameter of bur used (YT201:2mm and YT202:1mm ball burs) (Fig. 5b).

Conclusions

According to this in vitro study, we came up with the following conclusions.

(1) All fabricated Co-Cr copings showed the same marginal gap values.

(2) The marginal and internal gap of laser sintering copings were similar to that of cast Co-Cr copings.

(3) All Co-Cr copings showed clinically acceptable marginal and internal gap, regardless of fabrication methods (<120 μm). LSC copings have higher internal fitting.

(4) The shape and diameter of the bur and preparation of tooth, as well as the characteristics of the milling machine affect the adaptation of the copings obtained by the milling method.(5) Clinically acceptable crown copings can be made with each of the techniques examined. Although the compatibility of all produced Co-Cr copings is accepted, the production of the copings produced by the milling method should be more careful because of the milling drills and machine features.

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Legends Tables and Figure

Table 1 marginal and internal gaps

OAG

Groups	Mean	SD	Minimum	Maximum
CMC	137.40	94.71	13.15	499.30
LSC	90.41	75.32	17.Kas	551.99
CC	101.84	60.09	14.97	355.56

There was significantly different (*p*<0.05).

AIG

Groups	Mean	SD	Minimum	Maximum
CMC	144.49	98.02	14.91	499.30
LSC	94.30	76.15	17.Kas	551.99
CC	105.64	60.22	14.97	355.56

There was significantly different (*p*<0.05).

MG

Groups	Mean	SD	Minimum	Maximum
CMC	91.32	49.47	14.91	499,3
LSC	65.11	65.08	17,11	551,99
CC	77.16	53.70	14,97	355,56

There was not significantly different (*p*>0.05).

CSG

Groups	Mean	SD	Minimum	Maximum
CMC	132.97	50.91	32.06	224.54
LSC	90.79	81.72	24.75	383.77
CC	92.96	51.82	26.57	262.97

There was not significantly different (*p*>0.05).

CAG

Groups	Mean	SD	Minimum	Maximum
CMC	293.50	69.94	175.31	422.51
LSC	98.41	93.90	27.24	551.99
CC	112.36	49.04	33.15	299.99

There was significantly different (*p*<0.05).

AWG

Groups	Mean	SD	Minimum	Maximum
CMC	71.55	40.98	14.91	221.45
LSC	90.56	39.72	27.24	216.57
CC	98.04	30.81	33.15	169.34

There was not significantly different (*p*>0.05).

AOG

Groups	Mean	SD	Minimum	Maximum
CMC	71.48	38.34	16.36	168.91
LSC	76.98	29.47	31.54	129.99
CC	87.54	24.96	38.33	147.47

There was not significantly different (*p*>0.05).

OG

Groups	Mean	SD	Minimum	Maximum
CMC	197.88	77.39	91.95	499.30
LSC	158.85	80.05	24.40	363.02
CC	173.44	60.34	14.97	355.56

There was not significantly different (*p*>0.05).

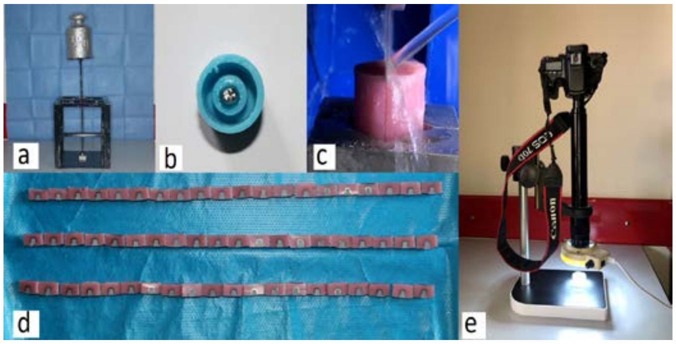

Fig. 1 (a) : Cementation with 50N force, (b) Silicon pattern, (c) Cutting line, (d) Cut all specimens ,(e) Video microscope

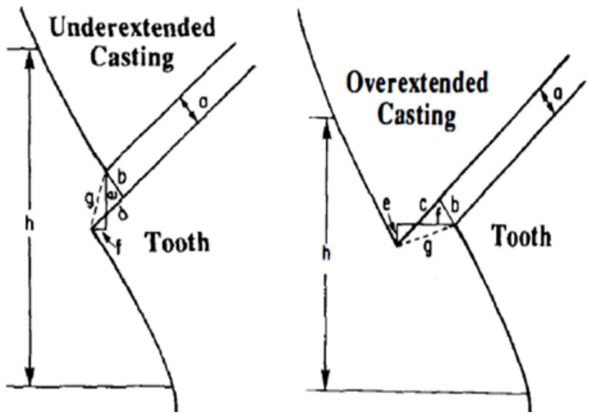

Fig. 2: Casting misfit terminology. (a) Internal gap, (b) Marginal gap, (measured in the this study) (c) Overextended margin, (d) Underextended margin, (e) Vertical marginal discrepancy, (h) Horizontal marginal discrepancy, (g) Absolute marginal discrepancy, (h) Seating discrepancy

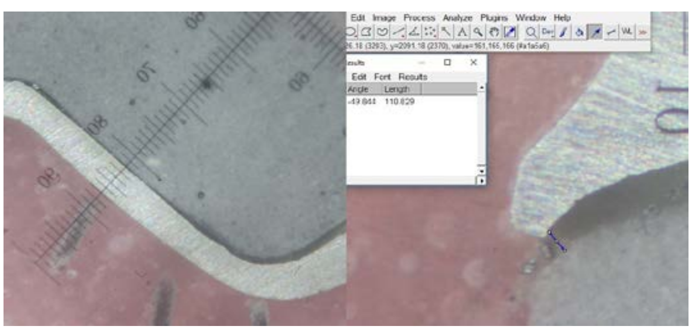

Fig. 3: Measurements in Image J software

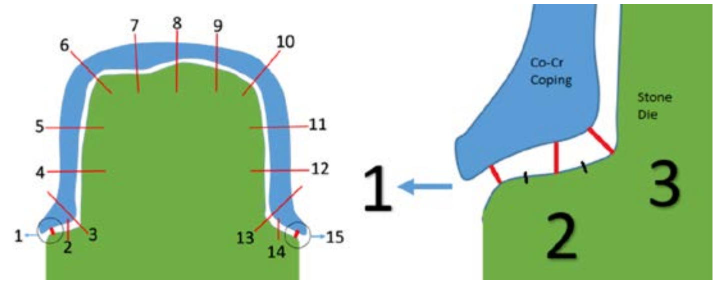

Fig. 4 : Marginal Gap (MG)(1. and 15. points), Chamfer Step Gap (CSG)(midpoint of step)(2. and 14 points), Chamfer Angle Gap (angle bisector) (CAG) (3. and 13. Points), Axial wall gap (AWG) (4.,5.,11. and 12.points), Axio-occlusal angle gap (AOG), Occlusal gap (OG) (7.,8. and 9. Points)

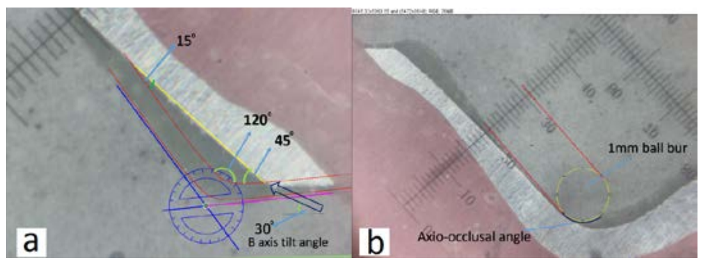

Fig. 5 (a): Chamfer convexity and B axis tilt , (b) axio-occlusal angle of drill diameter match

Abbreviation

OAG = Overall average gap, AIG = average internal gap, MG = marginal gap, CSG = chamfer step gap, CAG = chamfer angle gap, AWG = axial wall gap, AOG = axio-occlusal angle gap, OG = occlusal gap.