AL-AZHAR
Dental Journal
For Girls

The Official Publication
of The Faculty of Dental
Medicine For Girls,
Al-Azhar University
Cairo, Egypt.

Print ISSN 2537-0308 • Online ISSN 2537-0316

ADJ-for Girls, Vol. 6, No. 2, April (2019) — PP. 115:122

Effect of Different Wall Thicknesses on Fracture Strength, Marginal Accuracy and Translucency of Monolithic Ceramic Restorations

Marwa M. Abd El Aziz [1], Mona H. Mandour [2], Rania A. Shetawey [3]

Codex : 16/1904

azhardentj@azhar.edu.eg

http://adjg.journals.ekb.eg

DOI: 10.21608/adjg.2019.5457.1008

ABSTRACT

Purpose: The present study was conducted to evaluate the effect of different crown wall thicknesses (0.5mm, 1mm and 1.5mm) on the fracture load, marginal accuracy, and translucency of monolithic CAD-CAM manufactured lithium disilicate and Zirconia crowns. **Materials and Methods:** 60 monolithic single were constructed using CAD/CAM machine divided into two groups according to the material of construction Group (E): Monolithic IPS e.max CAD lithium disilicate crowns and Group (B): Monolithic BruxZir Solid zirconia based crowns. Each group was divided into three subgroups according to the axial wall thickness of the crown into Subgroup (0.5): 0.5 mm margin thickness, Subgroup (1): 1mm margin thickness and Subgroup (1.5): 1.5mm margin thickness. The Vertical Marginal gap was determined using Digital microscope, while translucency parameter was determined using a Spectrophotometer, then the fracture load was determined using universal testing machine and finally fracture pattern was detected by scanning electron microscope. The collected data were statistically analyzed. **Results:** Vertical marginal gap values for both groups (E and B) were within the acceptable clinical range. The translucency parameters (TP) values in group E revealed a higher mean value than in group B for all subgroups. The fracture load in group B revealed a higher mean value than in group E for all subgroups. **Conclusion:** Increasing the wall thickness can effectively increase the fracture strength while decrease the marginal gap and translucency of the monolithic lithium disilicate ceramic crowns and zirconia crowns.

KEYWORDS

Monolithic;
CAD-CAM; lithium disilicate;
Solid zirconia; wall thicknesses.

INTRODUCTION

In recent years, it has been introduced in the dental field, the monolithic crowns fabricated from several ceramic materials, as zirconia or lithium disilicate glass ceramic. These restorations reduced the risk of delamination associated with the classically veneered frameworks,

- Paper extracted from PHD thesis titled "Effect of Different Wall Thicknesses on Fracture Strength, Marginal Accuracy and Translucency of Monolithic Ceramic Restorations".

1. Specialist at El Matarya Teaching Hospital.
2. Professor of Crowns and Bridges, Faculty of Dental Medicine for Girls Al-Azhar University.
3. Assistant professor of Crowns and Bridges, Faculty of Dental Medicine for Girls Al-Azhar University.

reducing the production time with improved cost-effectiveness(1).

More importantly, the elimination of veneering layer in monolithic crowns is allowing more minimally invasive preparations and restorations.

Margin thickness is important, as it can determine the extent of sound tooth structure removal during preparation to get proper esthetic outcomes and structural integrity of the tooth-crown system. In addition, preserving more sound tooth tissue surrounding the cervical area by minimal preparation increases the long-term prognosis of the tooth; and helps to preserve the vitality of the pulp, thereby maintaining the health status of the host abutment tooth (2).

There is no enough information about how to minimize the thickness of restorations and to what extent decreasing the thickness of monolithic restoration affects fracture strength of the crown against mechanical loading especially in the more demanding posterior region, and to what extent this decreased thickness affects translucency of the final restoration as a major factor in controlling the esthetic outcome of ceramic restorations. Also, one of the important factors affecting the longevity and success of a restoration is the margin accuracy; and its relationship with the margin thickness. These are important factors in improving the outcome of a dental restoration, as the success of a restoration is evaluated by 3 major factors: resistance to fracture, esthetic value, and marginal accuracy.

Many studies have recorded the clinical performance of monolithic all- ceramic restorations and found that the existence of technical complications is low(3&4). However, in these studies, the reduction of the axial wall thickness was not investigated. Thus, the effect of this factor is still not obvious.

Therefore, the purpose of the current study was directed toward investigating the effect of different wall thicknesses ranging from 0.5mm, 1mm and 1.5mm of two types of monolithic all- ceramic crowns on their marginal accuracy, translucency, and fracture strength.

The null hypotheses tested were that different wall thicknesses of the two types of monolithic restorations will not affect the fracture strength, margin accuracy or translucency. In addition, within the same thickness for the two tested types of monolithic restorations, there will be no difference in the fracture strength, margin accuracy and translucency.

MATERIALS AND METHODS

Teeth selection

Three recently extracted sound mandibular second permanent molars were selected and used in this study. Selected molars were free from caries and restorations. Selected molars had similar dimensions measured using digital caliper (S235, Sylvac, Switzerland) in bucco-lingual and mesio-distal directions at the cement- enamel junction and at the highest convexity of the height of contour. The teeth were disinfected using 2.5% NaOCL solution for 3 hours and then cleaned from surface debris, stains and soft tissue with ultrasonic scaler (Woodpecker Piezoelectric 110V Piezo Ultrasonic Scaler UDS-J EMS Compatible, China.), and then stored in distilled water at room temperature throughout a course of the study to prevent them from dehydrating and becoming brittle.

Construction of epoxy resin blocks:

Each molar was embedded in the center of a plastic cylinder (2cm height and 2cm diameter) filled with epoxy resin (Kemapoxy 150 CMB 6th Oct., Egypt.).

Experimental design:

A total 60 (N=60) monolithic single crowns were constructed using CAD/CAM machine. The constructed restorations were assigned into two main groups according to the material of construction as following:

- **Group (E):** monolithic crowns constructed from IPS e.max CAD lithium disilicate ceramic (n=30).
- **Group (B):** monolithic crowns constructed from BruxZir Solid zirconia- based ceramic (n=30).

Samples of each main group were subdivided into three subgroups according to the axial wall thickness of the crown as following:

- **Subgroup (0.5):** Crowns constructed with 0.5 mm margin thickness, (n=10).
- **Subgroup (1):** Crowns constructed with 1mm margin thickness, (n=10).
- **Subgroup (1.5):** Crowns constructed with 1.5mm margin thickness, (n=10).

Teeth preparation:

Selected molars received standardized all ceramic preparations with the assigned three thicknesses of finish lines (0.5,1 and 1.5 mm) using special milling machine (CNC Centroid milling machine, USA.). The machine assembly incorporated a slow-speed straight hand-piece which is perpendicular to the machine platform. The criteria of tooth preparation are shown in Figure (1).

Verification of the finish line thickness:

The finish line thickness of each tooth was confirmed before milling the crowns by measuring one point in the middle of the finish line at each surface of each prepared tooth using digital calibration of the Exocad designing software (2015.07).

Fabrication of monolithic restorations:

- ***Optical impression:***

Each prepared tooth was sprayed with light reflecting powder (Telescan CAD white spray, Dental Future System, DIAMON, made in Germany) and secured on the tray of the scanner (Identica Hybrid blue scanner, MEDIT company, made in Korea) using Identica clay (MEDIT company, Korea) for taking optical impression. The scanning process of the tooth was completed, and a digital impression was captured for the tooth.

- ***Digital crown design:***

The margin of each preparation was traced. The CAD system designed the crown using designing software (Software designing Exocad 2015.07). Tools were used to adjust the required dimensions of the crown, according to the table (1).

Table (1): *Criteria of Crown Design.*

Subgroups (finish line thickness)	Crown margin thickness	Height of contour thickness	Occlusal thickness	Cement space
(0.5)	0.5mm	1.5mm	1.5mm	50µm
(1)	1mm	2mm	1.5mm	50µm
(1.5)	1.5mm	2.5mm	1.5mm	50µm

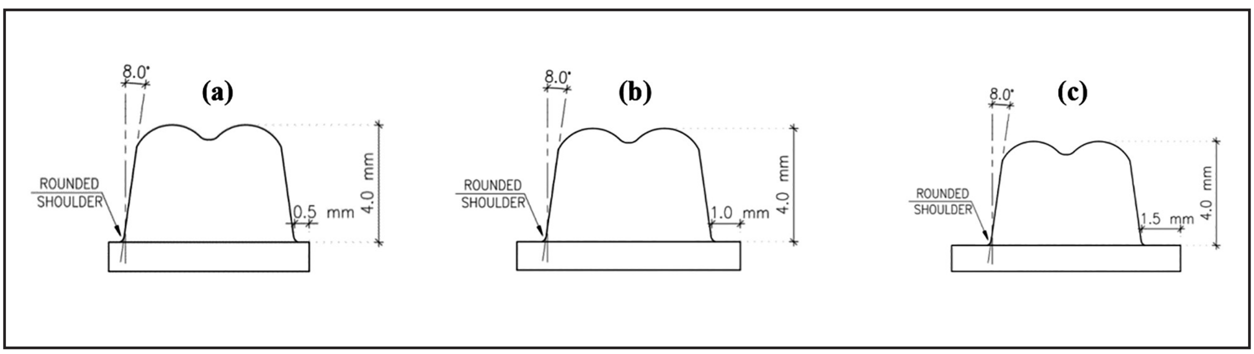

Figure (1): Diagram for the dimensions of the prepared molars.
Subgroup (0.5)**, (b)** Subgroup (1) and **(c)** Subgroup (1.5)

- ***Milling of the crowns:***

After finishing the design, milling was initiated for the monolithic crowns of both groups; Group (E) IPS e.max CAD lithium disilicate glass ceramic monolithic crowns (n=30) and Group (B) BruxZir solid zirconia- based monolithic crowns (n=30), using CAM 5- S1 VHF (5 axes) milling machine according to the manufacturer's instructions for each type of a ceramic restoration.

- ***Crystallization and Sintering of milled samples:***

After finishing the milling process, milled crowns were trimmed carefully using diamond abrasives at very low speed, to remove the excess of the materials at the site of connection with the ceramic block and blank, then the crystallization process for e.max CAD crowns and sintering process for the pre-sintered milled Bruxzir crowns took place.

- ***Achieving final shade:***

All restorations were completed by applying glazing materials (IPS e.max Ceram glaze stain liquid and paste Fluo. Ivoclar Vivadent AG, Liechtenstein Germany) then placing them on a thermal cotton pad in the furnace (Programat (P310) Porcelain Furnace, Ivoclar Vivadent AG, Liechtenstein Germany). The firing program was selected according to the manufacturer glaze firing temperature charts to achieve the final Vita shade (A2).

- ***Checking crowns' fit on the prepared teeth:***

The finished restorations were individually seated on their corresponding teeth and checked for complete seating using magnification lens (Magnifying lens, Ø75mm, China) (X=10).

Testing procedures:

- ***Marginal accuracy:***

The marginal accuracy of different groups and subgroups was estimated by measuring the vertical marginal gap values in (μm). Four equidistant landmarks were marked along the cervical circumference (two at the line angles and two equidistant points in between the line angles) on the cervical area of each surface (Mesial, buccal, distal, and lingual) that was left exposed above the epoxy resin level for each surface of the sample with a total of 16 readings along the circumferential margin of each crown. Shots of the margins were taken for each sample. Then morphometric measurements were done for each shot at 4 equidistant landmarks along the cervical circumference for each surface of the sample with a total of 16 readings along the circumferential margin of each crown. The measurement at each point was repeated five times.

- ***Translucency parameter:***

The translucency of the samples was measured using reflective spectrophotometer (Model RM200QC, X-Rite, Neu-Isenburg, Germany). The aperture size was set at 4 mm and the samples were exactly aligned with the device. The measurements were performed at the central area of bucco-cervical surface of each sample over a white and black backing relative to the CIE standard illuminant D65.

- ***Fracture strength determination:***

a) Duplication of the prepared teeth:

The three prepared molars representing each subgroup design were duplicated to produce a total of 60 epoxy dies for fracture strength determination. Each subgroup design was duplicated 20 times; ten samples for each material group (E and B).

b) Fracture strength:

Each sample (epoxy die and respective crown) was individually mounted on a computer controlled materials' testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with load cell of 5 kN. Fracture test was performed by the compressive load applied perpendicular on the middle of the central fissure of the occlusal surface.

Fractographic Analysis:

The fracture modes of samples were examined using the Scanning Electron Microscope (SEM) (Quanta 250 FEG (Field Emission Gun), FEI company, Netherlands). The analysis was started from the occlusal edge of the broken crown, from the upper part to the inner surface and terminated at the mesial and distal margin of the crown.

Statistical Analysis:

Data were presented as mean (M) and standard deviation (SD) values. As most of the data was parametric, so ANOVA test was used, followed by Tukey's post hoc test for pairwise comparison when ANOVA test yielded significant results. Independent (unpaired) t-test was used for two groups comparisons. Pearson correlation test was used to study the correlation between marginal accuracy and fracture resistance.

RESULTS

Statistical analysis of marginal accuracy:

Comparing groups (E and B) at 0.5,1 &1.5 mm finish line thickness, revealed a higher mean value in group E, with an extremely significant difference between both groups at (0.5mm) p<0.0001, and no significant difference at (1&1.5mm). (P=0.562 and P =0.305 respectively).

- ***Within Group (E):***

Within the different finish line thicknesses of the group (E); the highest mean marginal gap value was recorded at 0.5 mm followed by 1mm and the lowest mean value was recorded at 1.5mm thickness. ANOVA test revealed that the difference between subgroups was statistically significant (P<0.0001).

- ***Within group (B):***

Within the different finish line thicknesses of the group (B); the highest mean marginal gap value was recorded at 0.5 mm followed by 1mm and the lowest mean value was recorded at 1.5mm thickness. ANOVA test revealed that the difference between subgroups was statistically significant (P=0.011).

Statistical analysis of Translucency Parameter (TP):

Comparing groups (E and B) at 0.5,1 &1.5 mm finish line thickness, revealed a higher mean value in group E, with a significant difference between both groups at (0.5mm) p =0.04, with an extremely significant difference at (1mm) p <0.0001, and a significant difference at (1.5mm) p =0.002.

- ***Within Group (E):***

Within the different finish line thicknesses of the group (E); the highest mean TP value was recorded at 0.5mm followed by 1mm and the lowest mean value was recorded at 1.5mm thickness. ANOVA test revealed that the difference between subgroups was not statistically significant (P=0.530).

- ***Within group (B):***

Within the different finish line thicknesses of the group (E); the highest mean TP value was recorded at 0.5 mm followed by 1mm and the lowest mean value was recorded at 1.5mm thickness. ANOVA test revealed that the difference between subgroups was extremely statistically significant (P<0.0001).

Statistical analysis of fracture strength:

Comparing groups (E) and (B) at 0.5mm, 1mm, and 1.5 mm finish line thickness revealed a higher mean value in group B compared to group E, with an extremely significant difference between both groups (P<0.0001).

- ***Within Group (E):***

Within the different finish line thicknesses of the group (E); the highest mean value was recorded at 1.5 mm followed by 1mm and the lowest mean value was recorded at 0.5mm thickness. ANOVA test revealed that the difference between subgroups was extremely statistically significant (P<0.0001).

- ***Within Group (B):***

Within the different finish line thicknesses of the group (B); the highest mean marginal gap value was recorded at 1.5 mm followed by 1mm and the lowest mean value was recorded at 0.5mm thickness. ANOVA test revealed that the difference between subgroups was statistically significant (P=0.032).

Correlation between the vertical marginal gap and fracture strength:

Pearson's correlation test revealed a moderate negative correlation between the vertical marginal gap and fracture load (correlation coefficient R= -5.22). An increase in the vertical marginal gap was associated with a decrease fracture load and vice versa.

Fractographic analysis:

Examination of fractured samples revealed that all monolithic restorations failed due to complete bulk fracture of the crowns by splitting into several pieces. No die fracture could be detected. SEM analysis showed that the crack penetration started from the occlusal surface toward the inner side of the crown in all subgroups of both groups. The occlusal crack pattern was 'cone crack' in both groups (E and B), while the radial crack appeared in proximity to the cervical margin of subgroup E (0.5mm) as shown in figure (2).

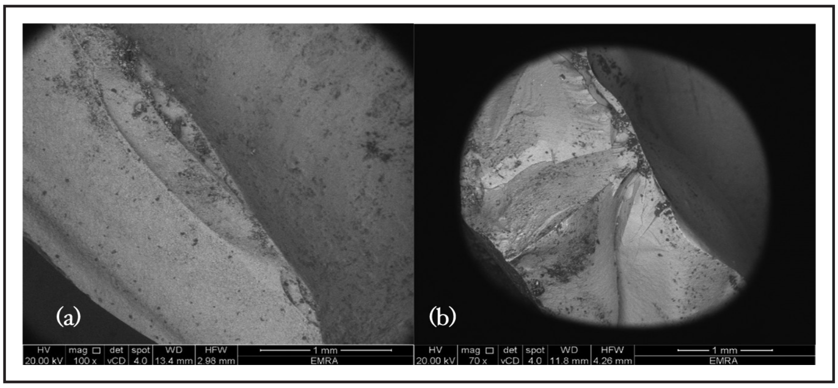

Figure (2): (a) SEM images of the marginal fractured surface of subgroup (E/0.5mm): (a and b) showing radial crack from the inner surface, and **(b)** SEM images of the occlusal fractured surface showing cone crack starting from the occlusal surface beneath the indenter site.

DISCUSSION

With the demand for a more conservative restoration, the monolithic all-ceramic restorations with reduced thicknesses are possible with the advent of new materials and techniques; it was essential to determine the minimal restoration's thickness which ensures a successful restoration. Therefore, the aim of the current study was directed toward examining the durability of monolithic restorations at different marginal thicknesses (0.5, 1, and 1.5mm) constructed from two types of ceramic materials (e.max CAD and Bruxzir zirconia) in terms of fracture strength, marginal accuracy, and translucency.

The selection of investigated crown wall thicknesses in the current study was made according to the recommendations of the respective manufacturers, while the occlusal thickness kept constant at 1.5mm in both groups.

In the present study, the marginal fit of tested monolithic crowns was measured without cementation to get the precise primary adaptation, which could be lost when cemented because of variations in cement type, viscosity, and cementation techniques [5] would affect the outcome results.

To ensure standardization of axial wall thicknesses among different samples; the relation between the thickness of axial walls at the margin and at the height of contour was kept constant. In addition, cement affects the fracture resistance and translucency of monolithic glass-ceramic restorations.

To detect marginal adaptation of tested samples in the current study, each of the investigated crowns in both groups with their different thicknesses had average marginal gap values of <47 µm which were well below the maximum clinically acceptable range which was reported among different studies for full ceramic crowns created by CAD/CAM before cementation between 23-74µm [6]. Therefore, according to these results both null hypotheses were rejecting.

In the current study, comparing groups (E and B), statistical results revealed a higher significant mean TP value in group E in different thicknesses. This may be due to as concluded in another study [7] that the range of translucency in ceramics at relevant thicknesses was resulted from different crystalline compositions. Variation in translucency may be due to differences in refractive index and crystal volume. Refractive index close to that of the matrix and less crystalline content may cause less scattering of light [8]. The results of the current study confirmed also that the variations in translucency among restorations are derived mainly from the type of ceramic. In general, glass-ceramics have greater translucency than the zirconia ceramics[9]. In addition, within the different thicknesses of each group (E and B); the highest significant mean TP value was recorded at 0.5 mm thickness and the lowest mean TP value was recorded at 1.5mm thickness. Increasing the thickness of the restorations significantly decreasing translucency and this is in agreement with a previous study [10] that found a significant increase in translucency was usually associated with a decrease in thickness. Therefore, according to these results both null hypotheses were rejecting.

The present study showed an average fracture load values ranging from 983–1984 N for e.max CAD crowns, group (E) and 3649–4626 N for Bruxzir crowns group (B) as the thickness varied from 0.5 mm to 1.5 mm. The average highest biting force in the posterior region was reported as 597N for females and 847 N for males with a maximum of about 900 N [11]. Therefore, regarding the results of the fracture test in the current study; all thicknesses in both groups seemed to achieve a higher fracture load required to withstand the biting forces in the posterior region. Therefore, according to these results both null hypotheses were rejecting.

Since other parameters, such as the crown shape and the height of the axial wall, which is known to influence the fracture resistance of posterior all-ceramic crowns [12], were standardized, it is considered that the difference in fracture load for both groups were related to the crown thickness and to the type of material.

In group E subgroup (0.5mm), the radial cracks were generated and extended along the axial surface of the marginal area representing one of the weakest regions of the crown structure as stress concentration area which might explain the lowest fracture load values obtained of this subgroup, as tensile stresses activated flexural radial cracking at the ceramic internal surface which remains an important mechanism of bulk fracture characteristic of glass-ceramic crowns.

While there was cone crack radiating out of the occlusal surface at thickness 0.5mm, 1mm, and 1.5mm, agreeing with the findings of previous study [13] which indicated that monolithic glass-ceramics are vulnerable to both occlusal surface damage and cementation internal surface fracture. Conversely, for thicker subgroups in the group (E) (1mm and 1.5mm), the cone crack mechanisms became predominant. The crowns showed high fracture loads as a result of high fracture energy which was able to generate added bifurcations in order to release high fracture energy [14], and have the potential to propagate down to the crown/cement interface, resulting in failure of the restorations.

While in group B, the cone crack mechanisms became dominates in all subgroups, with high fracture loads as a result of high fracture energy, indicating high fracture strength and mechanical properties of Bruxzir solid zirconia even at 0.5mm margin thickness.

The current study revealed a moderate negative correlation between the vertical marginal gap and fracture load. In accordance with another study [15] that stated the production method and the material composition influence the quality of the crown margin as well as the load at fracture. Therefore, increasing the marginal gap was a defect that could be considered a weak area that causing a decrease in the fracture load.

For better understanding and predicting the clinical performance of the two monolithic crowns with different wall thicknesses, future in vitro and in vivo studies should be conducted to focus on the factors mentioned above for a comprehensive assessment of the fracture behavior, marginal accuracy and translucency of monolithic lithium disilicate ceramic crowns, and monolithic zirconia crowns.

CONCLUSION

Within the limitations of the current study, it can be concluded that the wall thickness plays the major role in determining fracture strength, marginal accuracy, and translucency of monolithic lithium disilicate ceramic crowns and zirconia crowns. As the wall thickness increases, the fracture strength can increase while the marginal gap and translucency of the monolithic lithium disilicate ceramic crowns and zirconia crowns decrease.

ACKNOWLEDGMENT

The support of Al-Azhar University-Girls branch is acknowledged gratefully.

REFERENCES

- Guess PC, Zavanelli RA, Silva NR, Bonfante EA, Coelho PG, Thompson VP. Monolithic CAD/CAM lithium disilicate versus veneered Y-TZP crowns: comparison of failure modes and reliability after fatigue. Int J Prosthodont. 2010; 23: 434–442.
- Fragou T, Tortopidis D, Kontonasaki E, Evangelinaki E, Ioannidis K, Petridis H. The effect of the ferrule on the fracture mode of endodontically treated canines restored with fiber posts and metal–ceramic or all-ceramic crowns. J.Dent. 2012; 40: 276–85.
- Kern M, Sasse M, Wolfart S. Ten-year outcome of three-unit fixed dental prostheses made from monolithic lithium disilicate ceramic. J Am Dent Assoc. 2012; 143: 234–240.
- Sulaiman TA, Delgado AJ, Donovan TE. The Survival rate of lithium disilicate restorations at 4 years: A retrospective in vivo study. J Prosthet Dent.2015; 114: 364-366.
- Hamza TA, Ezzat HA, EL-Hossary MMK, Katamish HAEM, Shokry TE, Rosenstiel SF. The Accuracy of ceramic restorations made with two CAD/CAM systems. J Prosthet Dent 2013; 109: 83-7.
- Holmes JR, Sulik WD, Holland GA, Bayne SC. Marginal fit of castable ceramic crowns. J Prosth Dent. 1992; 67: 594-9.
- Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. (Pt 2) Core and veneer materials. J Prosthet Dent 2002; 88: 10-5.
- Clarke FJ. Measurement of color of human teeth. In: McLean JW, editor. Proceedings of the First International Symposium on Ceramics. Chicago: Quintessence; 1983. p. 441-90.
- Wolfart S, Wegner SM, Al-Halabi A. Clinical Evaluation of Marginal Fit before and after Cementation. Int J Prosthet Dent 2003; 16: 587-92.
- Mou SH, Chai T, Wang JS, Shiau YY. Influence of different convergence angles and tooth preparation heights on the internal adaptation of Cerec crowns. J Prosthet Dent 2002; 87: 248-55.
- Waltimo A, Kononen M. Bite force on single as opposed to all maxillary front teeth. J. Dent. Res. 1994; 102: 372–375.
- Scherrer SS, de Rijk WG. The effect of crown length on the fracture resistance of posterior porcelain and glass-ceramic crowns. Int J Prosthodont 1992; 5: 550–7.
- Zhang Y, Kim JW, Bhowmick S, Thompson VP, and Rekow ED. Competition of Fracture Mechanisms in Monolithic Dental Ceramics: Flat Model Systems. J Biomed Mater Res B Appl Biomater. 2009; 88: 402–411.
- Groten M, Huttig F. The performance of zirconium dioxide crowns: A clinical follow-up. Int. J. Prosthodont., 2010; 23, 429– 431.
- Schriwer C, Skjold A, Gjerdet NR, Øilo P: Monolithic zirconia dental crowns. Internal fit, margin quality, fracture mode and load at fracture. Dent Mater. 2017; 33: 1012–20.