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Impact of Position Within Blank and Sintering Temperature on Biaxial Strength of Yttria Gradiant Zirconia

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Abstract

To evaluate the impact of yttria content and sintering temperature on flexural strength of three different positions within yttria graded translucent zirconia blanks made with different multilayering strategies. Ninety disc shaped specimens were made from three different multilayered zirconia materials: Yttria Multilayer (KATANA), ZirCAD Prime and ZirCAD Prime Esthetic (IVOCLAR), samples were divided into nine groups (n=10) based on materials used and individual layers within blank for each material: yttria multilayer top, yttria multilayer middle, yttria multilayer bottom, ZirCAD Prime top, ZirCAD Prime middle, ZirCAD Prime bottom, ZirCAD Prime Esthetic top, ZirCAD Prime Esthetic middle and ZirCAD Prime Esthetic bottom. Top specimens were cut 1 mm below uppermost blank surface, middle specimens were taken from midpoint, and bottom specimens were cut from 1 mm above lowermost surface of blank. For 2 hours all specimens were sintered to final temperature according to manufacturer, then exposed to biaxial flexural strength test using the universal testing machine. Significant differences (P<0:001) were observed among individual three positions (Top, Middle and Bottom) within same blank of all three different multilayered zirconia materials. No significant differences (P>0:05) were noticed between bottom layers of yttria multilayer and ZirCAD Prime and between top layers of ZirCAD Prime and ZirCAD Prime Esthetic. The ZirCAD Prime bottom layer showed highest flexural strength (1130±3.333 MPa) and lowest value was for ZirCAD Prime Esthetic top layer (632.6±1.955MPa). Yttria gradient multilayered blanks have great reduction in flexural strength from bottom to the top incisal part irrespective strategy used for multilayering, yttria content was most influencing factor on layer strength compared to position within blank and sintering temperature. Therefore, several factors such as nesting strategies inside zirconia blank, prostheses type and desired aesthetical needs must keep in mind when using yttria graded multilayered zirconia blanks.

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Introduction

As peoples aesthetic demand rise, zirconia ceramic restorations which are both highly biocompatible and aesthetically acceptable have emerged as a powerful alternative to metal ceramic restorations [1,2].

Three percent yttria tetragonal zirconia polycrystals (3Y TZP) were the initial zirconia launched to the market which was principally made up of the tetragonal (t) phase. The transitional toughening process, which occurs when the t phase transforms to the monoclinic (m) phase, is responsible for the exceptional strength that is characteristic of 3Y TZP., when cracks start to appear they cause nearby t crystals to convert into larger more volumetric m crystals, which puts compressive stress on the crack and stops it from spreading [3,4].

Unluckily, the esthetic results of 3Y TZP were poor, and the presence of a tetragonal crystal phase is responsible for the inferior optical qualities of the zirconia material. Due to high opacity of 3Y TZP zirconia it could only be used as a framework for permanent fixed prosthesis and need to be overlaid with aesthetically pleasing feldspathic veneering materials [3,4].

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The addition of the cubic c phase and raise the yttria concentration allowed the dental industries to enhance the translucency of zirconia so new generations were developed 4Y and 5Y PSZ (4 and 5 yttria partially stabilized zirconia), unfortunately new versions showed a lower strength than 3Y TZP and more liable to fracture when used for making a fixed dental prosthesis [5].

As part of the process of developing monolithic restorations that are like natural teeth, manufacturers of zirconia have developed a novel multilayer yttria gradient zirconia. This zirconia has been launched in order to obtain both advantages of translucency of 4Y -5Y PSZ and the strength of 3Y TZP zirconia [6-8], the blank is made of strength graded translucent zirconia with varying crystal compositions and yttria concentration each layer, whereas high strength 3Y-TZP is used in the body cervical area, while a higher yttria 4-PSZ and 5Y-PSZ are utilized in top regions for greater translucency [6-8].

Because of the harmonious combination of its strength and its aesthetics, yttria graded multilayer zirconia is appropriate for wide range of indications from single unit crown to full arch esthetic restorations, because of its structural gradient which enables it to attain both good esthetics and mechanical performance, therefore gained a widespread agreement in the field of clinical practice.

Recent research has demonstrated that multilayer zirconia systems display significant variations in microstructure, yttria content, and phase composition that are depending on the layer, these variations have a significant influence on the mechanical qualities of fixed dental restorations, the findings of research conducted by Gomes and colleagues [9]. indicated that differences in the yttria concentration of multilayer zirconia had a considerable impact on the flexural strength of the material.

Furthermore, research [10] pointed that yttria strength gradient multilayered zirconia are planned to bring together very translucent with mechanically stronger layers, providing enhanced functional and cosmetic performance in monolithic restorations. Correspondingly, yttria content and size of the grains and their distribution are intimately related to microstructural features in multilayer zirconia, as demonstrated by Cho et al. [11]. Likewise, according to Ham et al. [12] flexural strength and surface characteristics can vary significantly across various multilayer zirconia systems, which are influenced by the composition and gradient patterns.

Besides compositional impacts, sintering conditions may also affect the resultant zirconia properties. For instance, Alatrash and Nalbant [13] established that sintering parameters substantially influence the microstructure and mechanical properties of multilayer zirconia ceramics.

Research on how multilayered zirconia's mechanical characteristics are affected by its location inside the blank is still few and has produced conflicting findings. Significant differences in the restoration strength made from various locations inside multilayer zirconia blanks were documented by Li et al. [14]. Furthermore, a considerable variation in the flexural strength and fracture toughness of cylindrical and bar shaped specimens composed of various yttria gradient multilayered zirconia layers have also been documented in several investigations [9,15-20].

On the contrary a numerous studies found little effect of positioning on prosthesis strength and statistically non-significant variations in the strength of restorations constructed from various locations inside yttria multilayered zirconia blanks [21-23].

Various multilayering technologies were used to create multilayered zirconia materials that available in the dental market. In this study, three translucent variable yttria content multilayered translucent zirconia blanks were used: ZirCAD Prime esthetic and ZirCAD Prime (Ivoclar Vivadent Inc., Schaan, Lichtenstein) and YML yttria multilayer (katana Noritake Kuraray Japan), manufactured with different multilayering strategies were used. Few studies on the mechanical properties of multilayered zirconia have explored the correlation between yttria content, the sintering temperature and location within zirconia blanks made with different manufacturing techniques, the aim of this study was to investigate the impact of position within zirconia blank and final sintering temperature on biaxial flexural strength of variable layers of yttia gradient zirconia blanks manufactured with variable multilayering strategies.

The null hypothesis proposed that biaxial strength of zirconia at three variable layers of each yttria graded blank are same, also the flexural strength at specific layer position of different yttria gradient zirconia blanks manufactured with various multilayering strategies and subjected to different final sintering temperature are same.

Materials and Methodos

Sample preparation

Disc sample designed with a 12 mm diameter and a 1.2 mm thickness (Figure 1) utilizing Autodesk meshmixer program (Autodesk, Inc. USA). A total ninety of discs shape samples were produced from three different yttria gradient multilayer zirconia blanks manufactured using various multilayering strategies, A thirty samples(n=30) were made from each zirconia blank, which subdivided into 3 subgroups of 10 samples (n=10) according to position within blank from which samples were taken (top T, middle M and bottom B), all blanks used were 98.5mm diameter and 14 mm thickness. Blank thickness selected was 14 mm as it available in market for all three types of zirconia. Three commercial materials were chosen for this investigation based on their distinct gradient profiles as stated by the manufacturers [24,25]: Yttria multilayered YML from KATANA (Kuraray Noritake Dental, Japan), Zircad PRime ZPR and Zircad PRime Esthetic ZPRE from (Ivoclar, Lichtenstein). Based on data provided by the maker, both Zircad Prime ZPR and Zircad PRime Esthetic ZPRE composed of three layers: incisal 3 mm, transition layer 4 mm and the remaining 7 mm represented cervical body, the incisal layer of Zircad PRime Esthetic ZPRE formed 21% of blank height made from 5Y, transition layer constituted 29% of blank height and manufactured from mixture of 4 and 5 YPSZ while remaining 50 % of blank was for cervical layer which made from 4Y PSZ. For Zircad PRime ZPR the percentages of three layers remained the same with variation that yttria contents were different as follow: 5Y, 3-5Y and 3Y for incisal, transition and cervical layer respectively. The Yttria multilayered YML blank consists of four layers: The incisal esthetic translucent layer 4.9 mm formed 35% of blanks with 4Y content, intermediate layer 4.2 mm subdivided into two layers of thickness 2.1 mm made 30% of blank synthesized from 3-4Y PSZ, while the bottom layer constituted the residual 35% and 4.9 mm of blank height manufactured from 3Y TZP (Figure 2).

The specimens were dry milled after the stereolithography (STL) file for the design was sent to the Coritec 350i milling machine (IMES-ICORE, Germany). To avoid any interference with the manufacturer's finishing touches or printed labels on the zirconia blank, outmost 1 mm on both top and bottom extremities of the blanks were excluded during the nesting process in CAM software. The top specimens (T) positioned 1 mm below the uppermost point of the blank incisal portion, whereas bottom specimens (B) were placed 1 mm above the lowermost point of the cervical bottom of the zirconia blank while the Middle specimens (M) were placed in the midpoint of the middle third (Figure3). All zirconia samples were prepared by same person, using a diamond cutting bur, the samples were detached from the zirconia blank following milling and their surfaces were dry polished 1200 grit silicon carbide abrasive (SiC abrasive paper P1200;Buehler USA) to retain the same level of surface smoothness Compressed dry air was used to clean each specimen surfaces completely, for removing any residual dust from the milling and polishing

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processes then using a zirconia-sintering Vita Zircomat 6000 MS furnace (Vita Zahnfabrik, Germany) all samples were conventionally sintered according manufacturer instructions with 2 hours holding time at final sintering temperature. Sintering's heat rise and cooling speeds were 8 degrees Celsius per minute 8^0C, based on manufacturer instructions the sintering temperature was 1550^0 C for YML and 1500^0 C for both Zircad PRime Esthetic ZPRE and Zircad Prime ZPR, the control panel of furnace was adjusted to change sintering temperature. Table 1 shows the studied groups specifications and sintering temperature of each one.

Strength test

Piston-on-3 ball test (the biaxial flexural strength BFS) test was performed for assessing the zirconia flexural strength of according to ISO 6872:2015 [26]. Biaxial flexural tests for disc samples were accomplished by placing specimens on 3 steel balls and piston apply load until fracture (Figure 4). A universal testing apparatus was employed to carry out the test (LLOYD LRX, AMETEK), the maximum load cause fracture of specimen was calculated using following standard formula in accordance with previous studies [27-31].

$\sigma = -0.2387P(X-Y)/d^2$

$X= (1+v)\ln(r_2/r_3)^2+[(1-v)/2](r_2/r_3)^2$

$Y= (1+v)[1+\ln(r_1/r_3)^2]+(1-v)(r_1/r_3)^2$

whereas σ is biaxial flexural strength in Megapascal (MPa), P is load at fracture in newton, d = specimen thickness at fracture origin in millimeters, v is Poisson ratio of ceramic, r_1= radius of support circle in millimeters. r2 = radius of piston tip in millimeters, r3=radius of specimen in millimeter.

Statistical analysis

One-way analysis of variance (ANOVA) test followed by post hoc test for pairwise comparison were employed to identify which of the nine layers differed significantly from each other with a significance level of P≤0:05 Using SPSS program version 27.0 (IBM SPSS Statistics; SPSS Inc. USA).

After that, a two-way analysis of variance ANOVA was performed for estimation the impact of position within blank, sintering temperature and the impact of their interaction on strength of variable yttria content zirconia.

Results

Means, standard deviation and level of significance of flexural strength data are shown in Table 2. Figure 5 displays bar graph of strength results. Significant differences were observed among the means of variable three positions (top, middle and bottom) within same blank of all three different multilayered blanks which constructed with different multilayering strategies (P≤0:05).

Highest flexural strength belonged to ZPRB group 1130±3.333 MPa followed by YMLB 1128±6.306 MPa while the lowest strength results was affiliated to ZPRET 632.6±1.955MPa group. When comparing a same layer position within different blanks the results as follow: for Top layers YMLT 740±1.763 MPa showed a significant difference with both ZPRET 632.6±1.955 MPa and ZPRT 635±2.449 MPa while a non-significant difference was found between ZPRET and ZPRT, for Middle layers a non-significant difference was observed between YMLM 999.2±8.134 MPa and ZPRM1000.4±10.564 MPa although both groups were significantly differed concerning strength values when compared with ZPREM 800±1.563 MPa , for Bottom layers ZPREB 840±2.788 MPa was significantly differed with other two bottom groups although no statistical difference was noticed between ZPRB 1130±3.333 MPa and YMLB 1128±6.306 MPa groups. Mean flexural strength of three positions for YML zirconia samples (955.7 MPa) was higher than that of ZPR (921.8 MPa), whereas mean of all samples produced from ZPRE materials (757.5 MPa) showed the least flexural strength values. Table 3 shows 2-way ANOVA results as a significant impact of zirconia material layers and sintering temperature on strength was noticed although a non-significant finding appeared related to the influence of their interaction on strength results.

Discussion

Monolithic fixed restorations made from yttria stabilized zirconia ceramic showed an extensive use in dental market due to their exceptional strength, superior aesthetics, simplicity of manufacture and increase productivity [32]. The flexural strength of zirconia dental materials is one of most important mechanical property used to evaluate their long-term clinical effectiveness [33].

International Organization for Standardization ISO defines standardized testing procedures for estimating the flexural strength of ceramics recommends the 4-point bending test, 3-point bend test and piston-on-3 ball test biaxial flexural strength (BFS) [26].

The present study examined flexural strength using piston on 3-balls (P3B) biaxial flexural strength tests due to the method's lengthy history of usage and recognized as one of most common methods for evaluating mechanical properties of brittle materials like zirconia ceramics [34-36].

Based on the BFS results the first part of hypothesis was rejected as our research findings presented that the strength values of various positions within same blank of each one of three different yttria graded multilayered blanks which manufactured using various multilayering strategies (YML, ZPR and ZPRE) used in this study were significantly differ from each other.

Current research revealed that the strength characteristic at different positions within same yttia gradient zirconia blank vary significantly from one another irrespective manufacturing strategy used during production process for different blanks.

The second part of hypothesis was partially accepted as non-significant differences were found between YMLB and ZPRB and between YMLM and ZPRM although each two groups were located within same level within blank, manufactured using different multilayering strategy and subjected to different final sintering temperature.

The harmony between the strength and translucency features of newly introduced multilayered highly esthetic zirconia materials considerably affects their clinical performance [4,37].

This study assessed the flexural strength of variable layers of yttria gradient zirconia blanks were produced using three different multilayering strategies, the YML blank from Kurary Noritake manufactured with four layers one cervical bottom 35%, one incisal 35%and two intermediate layers 15%+15%, the yttria graduation of layers was 3Y, 4Y and 3-4Y respectively. The other two blanks ZPR and ZPRE were produced from same manufacturer Ivoclar composed of three layers cervical, intermediate and incisal layers, both blank shared a criteria that incisal layer constitute uppermost 3mm of blank and the following 4 mm for intermediate layer whereas the remaining millimeters represents the cervical layer irrespective blank thickness, however these two blanks were differ in yttria multilayering strategy whereas incisal 3mm of both of them made from 5Y, bottom of ZPR from 3Y and bottom of ZPRE from 4Y and according manufacturer information the intermediate 4 mm layer of each one composed from blend of two zirconium oxide raw materials of incisal and bottom ingredients of same blank.

Our study revealed a significant difference in flexural strength between different layers position within same blank, these variations between layers showed a strength-gradient behaviors in descending order from highest strength at bottom to lowest strength at top, these results are consistent with earlier work [9,16,17]. Gomes et al. [9] study demonstrating that yttria graded zirconia blanks has a top esthetic layer with strength equivalent to higher yttria content zirconia and a bottom layer strength similar to results previously published for lower yttria content zirconia, our research findings corresponds closely with those of Strasser et al. [16] who demonstrated a

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higher cubic phase fractions and lower strength in 5Y-TZP enamel top layers compared to 3Y-TZP dentin bottom layers, and with the data of Inokoshi et al. [17] who observed an analogous correlation between phase composition, yttria content and flexural strength which confirms that higher Y2O3 contents reduce the potential for stress-induced transformation toughening due to greater cubic phase [38,39]. This explains why strength of middle layer of all three blanks possess an intermediate strength between top and bottom layer of each yttria graded blank as this layer composed from material mix ingredient of top and bottom and containing yttria higher than bottom and lower than top to emphasize homogenous graduation strategy and get a seamless progression transitional zone.

According to the present study , ZPRB group exhibited the highest strength, followed by YMLB, the reason why these two bottom layers have the highest strength due to fact that these both two bottom layers were made from 3Y TZP, which is totally composed of a t phase that is capable of undergoing transition toughening when subjected to stress [3,40], this process involves t-m phase conversion, which causes a raising the grain volume making a compression on material surface, this process resists cracks initiation that happened throughout the restorative manufacturing step, and it stops future cracks from propagating which ultimately results in an improvement in the strength properties [36,40], and for the same reason strength of these two bottom layers was significantly differ from ZPREB due to fact that the letter made from 4Y PSZ so it containing a less t phase and more high esthetic low strength cubic phase making it weaker and less capable of withstanding a high flexure forces.

The lowest flexural strength results were for top layers ZPRT and ZPRET whereas no significant difference was found between these two groups, this may be attributed to that both layers were made from same ingredient high yttria content 5Y PSZ and high amount of low strength cubic (c) phase and subjected to the same sintering temperature and holding time, this confirmed with a study declared that no differences was noticed microstructurally regarding grain size between the layers of gradient multilayered have the same yttria content when subjected to conventional sintering [41]. Another study [10] confirms these results revealed that the quantity of yttria found in the Zircad PRIME cervical layer was consistent with a material that contained 3Y%, but the amount of yttria found in the incisal translucent layers was 5Y PSZ, , the incisal layer is more aesthetically pleasing but has the lowest values for flexural strength, this may be attributed to it stabilized with a higher yttria concentration of 5 mol% and contains a higher content of weak c phase. When the yttria concentration and cubic phase are increased, the microstructural level of the created metastable tetragonal phase is reduced [39, 42-43]. Because zirconia-containing higher cubic materials influence transformation toughness, the strength of this layer will be reduced [42,43], consequently, compared to the cervical layer, the incisal translucent layers flexural strength negatively affected by a higher level of yttria and cubic phase.

The above mentioned reasons explains why the mean of all YML specimens was higher than ZPR specimens and ZPRE was the least, as YML block compose of 3Y and 4Y and not containing 5Y , ZPR block made from 3Y and 5Y with fact that half of the block was constituted from 3Y and ZPR constructed from 4Y and 5Y, whereas YML had a least cubic followed by ZPR and the highest amount of cubic phase was existed in ZPRE block, consequently because of the differences in c phase and yttria content the strength varies Even though adding more yttrium oxide improved the translucency of zirconia, the material's mechanical strength decreased.

Results of current study no coincide with results of a recent study Inokoshi [17] which showed a much lower values than our measurements regarding flexural strength for different layer within blank of yttria graded YML and Zircad Prime, additionally study found a statistic difference between intermediate layers of ZRP and YML bottom layer although used the same blanks and same sintering conditions as applied in our study, this may related to the different methodology and sampling as Inokoshi [17] used the 4 point flexural strength test for Plate shaped specimens manually made with the specimens' edges were chamfered at a 45° angle instead of disc shape samples designed through software and milled with machine as done in our study, furthermore a difference in in samples location was noticed whereas the Prime transition layer samples incorporated some enamel layer, the YML body 1 layer samples involved some enamel incisal layer and YML body 2 layer samples included some body 3 layer.

Our research results revealed a strong correlation between flexural strength of zirconia and percentage of yttria, consequently from scientific viewpoint the impact of sintering temperature may be applicable only when making a comparison between groups sharing same yttria content and varies only in sintering temperature as a comparison between YMLB and ZPRB whereas both layers were made from same yttria content 3Y, but YMLB sintered at 1550^{0}C and ZBRB sintered at different temperature 1500^{0}C. Current research results showed a non-significant differences between them, this agrees with result of recent study [2] results which also showed a no differences statistically between dentine bottom layers of two types of multilayered zirconia (shade gradient and yttria gradient) sintered at different temperature but share in same yttria content in bottom layer, this emphasize crucial effect of cubic phase and yttria content on material strength and this explains why a significant difference was found between ZPRM and ZPREM although both layers shared same position within blank and same sintering temperature and same multilayering strategy but differ in yttria content, this confirm that yttria content with cubic phase most influencing rather than temperature on strength of conventionally sintered zirconia , additionally the previously mentioned reasons clarify why no significant difference was found between ZPRB and YMLB although both were sintered at different final temperature but made from same yttria content zirconia.

For our study bottom dentin layer of YML material which sintered at 1550^{0}C was lower but without statistical different when compared to bottom of ZPR which sintered at 1500^{0}C although both were made from similar yttria content 3Y , this slight variation of result is in a line with previous study [44] stated that for the 3Y zirconia ceramic when sintered for 2 hours, microstructurally a reduction in the average size of pores was detected when a decrease in sintering temperature from 1550^{0}C through 1500^{0}C, it is proposed that raising the sintering temperature to 1550°C causes the original powder to recrystallize more quickly and grains grow, then there will be shrinking in the spots where the original powder was not evenly distributed, subsequently a number of large pores were created under these conditions as these pores consider as cleavage fracture area reducing strength of material.

Computer-assisted design and computer-assisted manufacturing (CAD/CAM) systems were used in dental laboratories to create fixed dental restorations using multilayered zirconia blanks [45]. The dental technician can utilize computer-aided manufacturing (CAM) software to position up and down the planned prosthesis precisely within the zirconia blank that is mounted later to the machine. However, technician must be careful at the step of fixed prosthesis placement inside translucent zirconia yttria multilayered blank during machine milling procedure as strength of its different layers not same. These procedures greatly affect the clinical outcome of fixed dental prostheses, especially when sensitive parts like connectors are situated in the incisal or transitional layers [22,46-48].

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Understanding exactly how variations in multilayering construction technologies impacts the strength characteristics of multilayered zirconia are essential for both dental professionals and technicians, and this study's findings show that different manufacturing strategies can considerably affect the flexural strength of the zirconia material.

Dentists and technicians can make better treatment planning decisions and higher prognosis restorations by having a comprehensive understanding of the mechanical and esthetic characteristics of multilayered zirconia. By having comprehensive information of the strength and aesthetics of the many multilayered esthetic zirconia blank options in market, they can select the material that is the best suitable for the specific requirements of each individual patient enabling improved functional and aesthetic performance of monolithic restorations. The technician should perform correct positioning of the STL of the designed fixed dental prosthesis within yttria graded blank in CAM software during manufacturing process to achieve maximum of restoration strength without compromising esthetic outcomes, as the nested positions inside CAM software for yttria graded blocks will affect their strength and translucency. Dentists and technicians' communication promote an effective teamwork which accomplishes durable and long lasting fixed dental prosthesis for optimal patient outcome,

Use of disc shaped specimen for testing is one of the limitations of our study, therefore for valuable understanding the flexural strength of different yttria graded esthetic multilayered zirconia blanks future research should use samples that are analogous to restorations such as crowns and three-unit fixed prosthesis in order to mimic failures as it occurs in clinical situations. Further studies are necessary for evaluating how placement techniques and location inside blank influences strength of full anatomic prostheses made from yttria graded blank. Additionally, the grain geometry and microstructural composition of each layer must be analyzed in further studies.

Conclusion

The study's findings lead to the following conclusions:

1-Flexural strength values for yttria graded zirconia varied across three layers, irrespective strategy employed during manufacturing process, regarding strength features yttria content is most influencing factor compared to position within blank and sintering temperature.

2-The bottom dentine layer of all yttria graded zirconia blanks stronger than all other layers within same blank and top incisal layer strength was the lowest among three layers within same blank.

3-Strength characteristics are not the same for specific layer position within blanks of yttria graded zirconia blank made with different multilayering strategy so technician must have knowledge about mechanical and esthetic properties of different zirconia blanks to select appropriate blank for each specific clinical situation.

4-Multilayered blanks with different content of yttria per layer have excessive decrease in flexural strength from bottom to the top incisal part so position of prosthesis within the blank during nesting process in CAM software is critical for balancing between strength criteria and aesthetic outcome for restoration.

5-Specific layers of same position within blanks manufactured with different multilayering strategy and sintered conventionally for 2 hours but sharing the same yttria content their strength not highly affected when sintered at 1500°C and 1550°C.

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Conflicts of Interest

The author declares no conflicts of interest in this work.

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and Embrasure Shaping Methods. J Prosthodont. 2019 Jan;28(1):64-70. doi: 10.1111/jopr.1300.

Figure 1. Disc shape sample using designing meshmixer software.

Figure 2. Different multilayered zirconia blocks used and features of each specific layer.

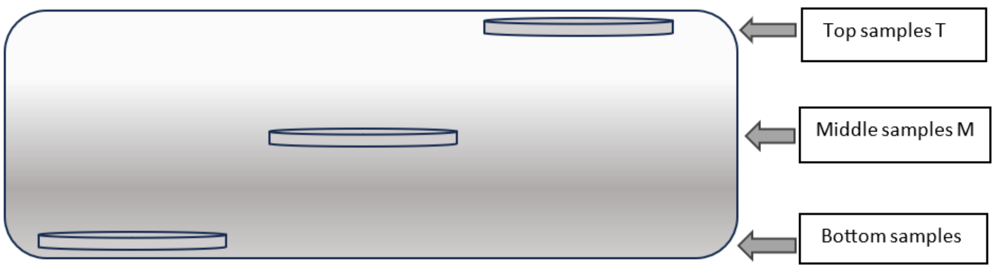


Figure 3. Position within blank of specimens in CAM software during nesting process.

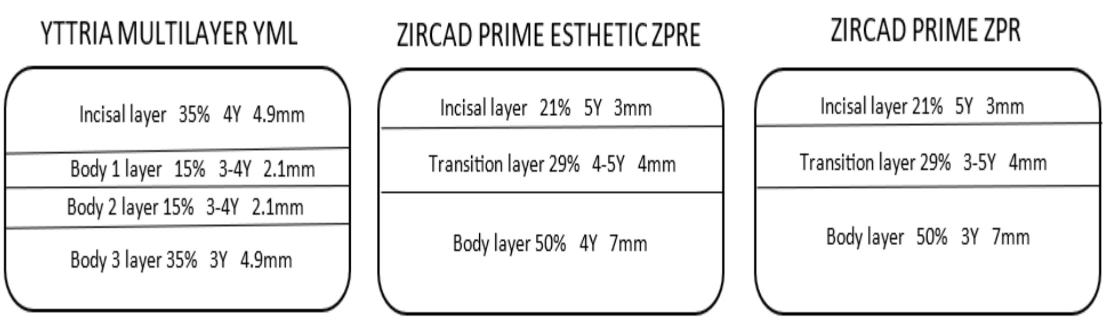
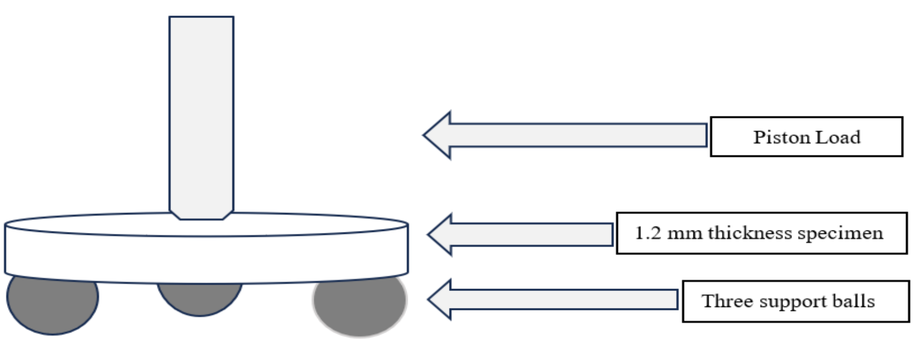


Figure 4. Piston on three balls biaxial strength test for of zirconia disc specimen.



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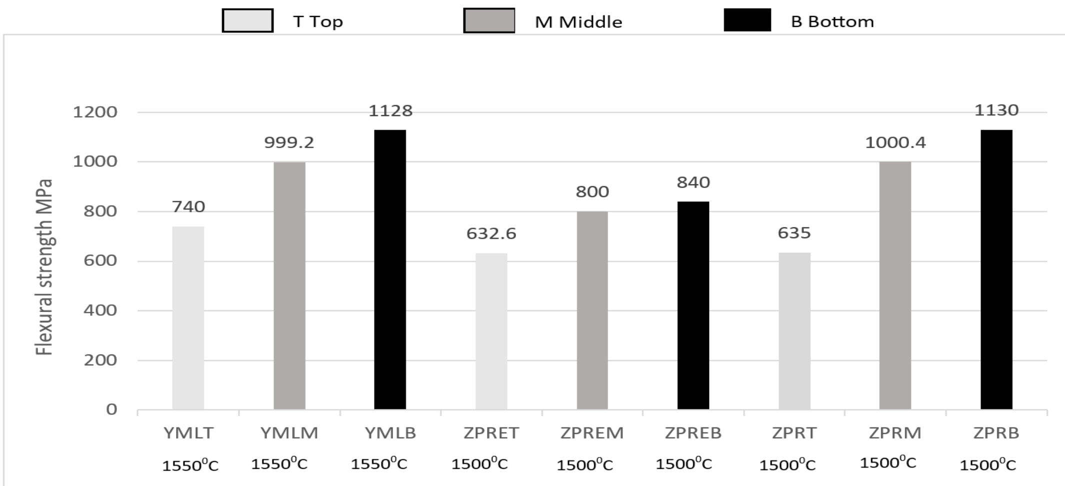

Figure 5. YMLT yttria multilayer top, YMLM yttria multilayer middle, YMLB yttria multilayer bottom, ZPRT ZirCAD Prime top, ZPRM ZirCAD Prime middle, ZPRB ZirCAD Prime bottom, ZPRET ZirCAD Prime Esthetic top, ZPREM ZirCAD Prime Esthetic middle and ZPREB ZirCAD Prime Esthetic bottom.

Table 1. Classification depending on yttria content, sintering temperature and specimens layer position within blank and of each group.

Group	Blank type	Sample position	Yttria content	Sintering Temperature
YMLT	YTTRIA MULTILAYER KATANA	Top	4Y	1550⁰C
YMLM	YTTRIA MULTILAYER F KATANA	Middle	3-4Y	1550⁰C
YMLB	YTTRIA MULTILAYER KATANA	Bottom	3Y	1550⁰C
ZPRET	ZIRCAD PRIME ESTHETIC IVOCLAR	Top	5Y	1500⁰C
ZPREM	ZIRCAD PRIME ESTHETIC IVOCLAR	Middle	4-5Y	1500⁰C
ZPREB	ZIRCAD PRIME ESTHETIC IVOCLAR	Bottom	4Y	1500⁰C
ZPRT	ZIRCAD PRIME IVOCLAR	Top	5%	1500⁰C
ZPRM	ZIRCAD PRIME IVOCLAR	Middle	3-5Y	1500⁰C
ZPRB	ZIRCAD PRIME IVOCLAR	Bottom	3Y	1500⁰C

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Table 2. Means and standard deviation SD for l strength values of the study.
a, b, c: No significant difference between groups shares the same letter, YMLT yttria multilayer top, YMLM yttria multilayer middle, YMLB yttria multilayer bottom, ZPRT ZirCAD Prime top, ZPRM ZirCAD Prime middle, ZPRB ZirCAD Prime bottom, ZPRET ZirCAD Prime Esthetic top, ZPREM ZirCAD Prime Esthetic middle and ZPREB ZirCAD Prime Esthetic bottom.

GROUP	Flexural Strength Mean (MPa)	SD	Minimum	Maximum
YMLT	740	1.76383	737.00	743.00
YMLM	999.2[a]	8.13497	988.00	1010.00
YMLB	1128[b]	6.30696	1115.00	1135.00
ZPRET	632.6[c]	1.95505	629.00	635.00
ZPREM	800	1.56347	798.00	802.00
ZPREB	840	2.78887	835.00	845.00
ZPRT	635[c]	2.44949	630.00	640.00
ZPRM	1000.4[a]	10.56409	980.00	1010.00
ZPRB	1130[b]	3.33333	1124.00	1136.00

Table 3. Two-way ANOVA results of zirconia material layers, sintering temperature and effect of their interaction on strength.

Source	Type III Sum of Squares	Degree of Freedom	Mean Square	F	p-value
Corrected Model	2393832.622	5	478766.524	64.491	0.000
Intercept	64469223.2	1	64469223.2	8684.172	0.000
layer	1929548.8	2	964774.4	129.958	0.000
Temperature	269429.422	1	269429.422	36.293	0.000
layer * Temperature	7426.844	2	3713.422	0.5	0.608
Error	623596	84	7423.762		
Total	7245319	90			
Corrected Total	3017428.622	89			