Effect of Different Ceramic Crown Preparations on Tooth Structure Loss – An In Vitro Study

by


A thesis submitted in conformity with the requirements for the degree of Master of Science
Faculty of Dentistry
University of Toronto

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Abstract

Objective: To quantify and compare the amount of tooth-structure reduction following the full-coverage preparations for crown materials of porcelain-fused-to-metal, lithium disilicate glass-ceramic and yttria-stabilized tetragonal zirconia polycrystalline for three tooth morphologies.

Methods: Groups of resin teeth of different morphologies were individually weighed to high precision, then prepared following the preparation guidelines. The teeth were re-weighed after preparation and the amount of structural reduction was calculated. Statistical analyses were performed to find out if there was a significant difference among the groups.

Results: Amount of tooth reduction for zirconia crown preparations was the lowest and statistically different compared with the other two materials. No statistical significance was found between the amount of reduction for porcelain-fused-to-metal and lithium disilicate glass-ceramic crowns.
Conclusion: Within the limitations of this study, more tooth structure can be saved when utilizing zirconia full-coverage restorations compared with lithium disilicate glass-ceramic and porcelain-fused-to-metal crowns in maxillary central incisors, first premolars and first molars.
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### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>PFM</td>
<td>porcelain-fused-to-metal</td>
</tr>
<tr>
<td>LDGC</td>
<td>lithium disilicate glass-ceramic</td>
</tr>
<tr>
<td>Y-TZP</td>
<td>yttria-stabilized tetragonal zirconia polycrystalline</td>
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</table>
Chapter 1: Introduction and Literature Review

Introduction

The ability of tissue regeneration is non-existent in the hard tissues of the tooth. Consequently, once those tissues are congenitally deficient or lost due to caries, trauma or physiologic wear, they need to be replaced by various restorative materials to reestablish mainly the function and aesthetics of the tooth in the most conservative manner(1).

Teeth require preparation to receive restoration. To ensure the long term success of the treatment, the preparations should be based on the following main principles(2):

1. Preservation of tooth structure
2. Retention and resistance
3. Structural durability
4. Marginal integrity
5. Preservation of the periodontium

Restoring teeth at minimal biologic cost is a fundamental principle of tooth preparation that affects the postoperative vitality and sensitivity as well as long-term prognosis of the restored tooth as well as the restoration(2, 3). Biologically, it decreases the impact of the procedures as well as the subsequent effect of the materials for cementation of the restoration. The thickness of the remaining dentin has been shown to have an inversely proportional effect on the health of the pulp(1). Mechanically, tooth structure preservation provides better retention and resistance forms.(4)

Considering the durability, for many years porcelain-fused-to-metal (PFM) crowns have been the material of choice for single crowns and fixed dental prosthesis (FDPs)(5). However, with
the advancements in ceramic materials and their fabrication technology in recent years, the usage of all-ceramic crowns has significantly increased (6).

Current restorative materials utilized in dentistry have diverse mechanical and aesthetic properties. These individual properties necessitate restorations of different thicknesses and consequently different amount of tooth structure reduction. Therefore, to preserve tooth structure, it is essential to optimally select the restorative material based on the patients’ wish and the clinical circumstances.

**Dental Ceramics in Dentistry**

Aesthetic tooth-colored restorations have been in the highest demand specifically in recent years (6). The major tooth-colored restorative materials are dental porcelains and resin composites. Tooth-colored resin composite materials have several disadvantages such as gradual degradation in oral cavity, shade and color instability and inferior mechanical properties compared to porcelain (6).

This increasing demand inspired the dental industries to explore the enhancement of different mechanical and aesthetic properties of porcelain as well as the advancement of the technologies involved in fabrication of dental porcelain. These further efforts lead to the introduction of new ceramics such as lithium disilicate glass-ceramic (LDGC) and yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) that present higher aesthetics and mechanical properties compared with their predecessors (7, 8).

**Classification of Dental Ceramics**

Dental ceramics can be classified based on different properties (9). For simplicity, three main categories of ceramics based on glass-content are initially presented.

a) Predominantly glass ceramics (e.g., lithium disilicate glass-ceramic)
b) Particle filled glass ceramics (e.g., alumina)
c) Polycrystalline ceramics (e.g., Y-TZP)

Initial ceramics used in dentistry were feldspathic ceramics. At infancy, glass ceramics were produced by mechanically adding crystalline filler particles to the glass prior to firing. The contemporary technique for glass ceramic production involves growing of the filler particle inside the glass object as in Ivoclar Vivadent LDGC, so called “IPS e.max” product(9).

Due to the inferior mechanical properties of glass ceramics as well as colorlessness and transparency of these ceramics, other particles such as aluminum oxide and leucite were added to them to enhance the properties. These ceramics are known as particle filled glass ceramics(7).

Despite the impeccable aesthetics of glass ceramics, the mechanical properties were far less than porcelain-fused-to-metal or full metal restorations. That said, the next generation of ceramics presented significantly higher mechanical properties. Polycrystalline ceramics (such as Y-TZP) have flexural strength and mechanical properties comparable to metal alloys. They have no glassy phases. They consist of atoms that are densely packed into regular arrays, which increases the mechanical properties significantly higher than the glass ceramics with loose and irregular network of atoms. To add to the excellent mechanical properties, the so called “fracture toughness” of zirconia which is resistance to crack propagation due to the volume changes of this material once it cracks, made this material exceptionally popular in recent years.

Fusing temperature is another approach to classify the dental ceramics. Subsequently, ceramics can be divided into the following groups:

a) High-fusing (1315°-1370° C)
b) Medium-fusing (1090°-1290° C)
c) Low-fusing (870°-1065° C)
d) Ultra-low-fusing (870° C)
Based on the nature and amount of crystalline phase dental porcelains can be classified into the subsequent groups:

a) Feldspar (KAlSi$_3$O$_8$) (e.g., Vita Mark II)
b) Leucite (KAlSi$_2$O$_6$) (e.g., IPS Empress)
c) Mica (KMg$_2$.5Si$_4$O$_{10}$F$_2$) (e.g., Dicor)
d) Alumina (Al$_2$O$_3$) (e.g., In-Ceram Alumina)
e) Spinel (MgAl$_2$O$_4$) (e.g., In-Ceram Spinel)
f) Lithium disilicate glass-ceramic (Li$_2$Si$_2$O$_5$) (e.g., IPS Empress 2)
g) Yttria-stabilized zirconium oxide (ZrO$_2$) (e.g., Y-TZP Cubes)

Properties of Various Ceramics

The flexural strength represents the highest stress experienced within the material at its moment of yield. It is a measure showing the strength of a material and it is measured by mega pascal (MPa)(10).

Historically, predominantly glass ceramics had the lowest flexural strength of around 60 to 70 MPa. By adding leucite, the flexural strengths of leucite-reinforced ceramics were increased to around 120 to 150 MPa. The new glass ceramics such as Ivoclar Vivadent lithium disilicate glass-ceramic have much higher flexural strength (≥500 MPa)(11).

Monolithic polycrystalline ceramics specifically Y-TZP, has the highest flexural strength. Currently, there are three different Y-TZP products in the market of North America with different aesthetics and subsequent different flexural strengths(12).

The most aesthetics Y-TZP monolithic ceramic has a flexural strength of slightly less than 800 MPa(13). The Y-TZP monolithic material with the highest flexural strength is extremely opacious with the flexural strength of about 1400 MPa(13). There is another Y-TZP monolithic ceramic with 1100 MPa flexural strength that is less aesthetic but stronger than the former group and apparently less strong but more aesthetic than the latter group(13).
It should be noted that clinically, other than the mechanical properties of the ceramic, the strength of single unit restorative materials depend on various factors such as the thickness of the material, the stiffness of the support (elastic modulus), the type and thickness of the cement, the loading and contact areas, Patients’ parafunctional habits as well as the forces applied by the opposing dentition or prostheses(4, 12).

To add to the above, in multiple unit prostheses, failure functions linearly with connector width, with the square of connector height, radii of curvature (the smaller the radii, the weaker the connector) and the condition of the abutment tooth(14).

**Significance of Preparations for Dental Restorations**

To ensure the success of a Prosthodontic treatment, preparations must be based on fundamental principles of tooth preparation. A good preparation warrants the success of the subsequent procedures such as the interim restoration, impression for definitive prostheses, pouring of dies and casts and waxing(15).

In general, the principles of tooth preparation may be divided into three major categories(2):

a) Biologic applications, which affect the health of the oral tissues.
b) Mechanical considerations, which impact the integrity and durability of the restoration.
c) Aesthetic considerations, which satisfy the appearance for the patient.

All the above-mentioned factors should be simultaneously observed to assure the long-term success of the treatment. Improvement in one area often negatively affects another area, and seeking perfection in one may lead to failure in another. For example, in the fabrication of a metal-ceramic crown, adequate thickness of porcelain is required for an aesthetic lifelike appearance. That being said, if excessive tooth structure is removed to accommodate more
thickness of porcelain for aesthetic reasons, the pulpal tissue may be traumatized (biologic issues) and the tooth improperly weakened (mechanical consideration)(16). In-depth knowledge and an understanding of the different criteria are prerequisite to the development of satisfactory tooth preparation skills. Predictable accomplishment of optimum tooth preparation often includes finding the best combination of compromises among the applicable biologic, mechanical, and esthetic considerations(4).

Guidelines and Recommendations

Full-coverage restorations exhibit higher retention and resistance forms compared with other partial restorations. That said, it does not mean that this type of restoration should be used on every tooth. Instead, it should be used on those teeth whose configuration demands maximum retention. As an example, most of the single unit restoration clinical scenarios would not require maximum retention. On the contrary, fixed dental prosthesis specifically with shorter clinical crowns (less than 3 mm for anterior teeth and less than 4 mm for posterior teeth) or longer spans would necessitate maximum retention and resistance forms(17).

Porcelain-Fused-to-Metal

Metal-ceramic restoration, also called porcelain-fused-to-metal restoration, consists of a porcelain veneer bonded to a metal coping that covers the prepared tooth. This combination provides the strength and accuracy of fit of a cast metal coping with the liveliness and aesthetics effect of a ceramic crown. With a metal substructure, these restorations have greater strength than monolithic ceramic restorations. Previously conducted studies’ results showed that metal-ceramic restorations are significantly stronger than monolithic ceramic restorations(18). Consequently, these restorations have been historically used in a wider variety of situations, where stronger restorations were required; including the replacement of missing teeth with fixed dental prostheses. As discussed previously, with the advancement in ceramic
materials and their fabrication technology in recent years, some monolithic ceramic restorations are exhibiting comparable mechanical properties to porcelain-fused-to-metal.

As the restoration consists of two layers of metal and porcelain, the preparation should be performed in a manner that provides space for the thickness of both layers of material. In anterior teeth, the reduction on the facial surface is more significant to provide space for the substructure and a layer of porcelain thick enough to achieve the optimal aesthetic result. There is shallower reduction similar to a preparation for a full metal crown on the lingual surface(2). Failure in adequate tooth reduction will result in over-contouring the restoration that in turn will impact on the aesthetics of the restoration; i.e. the shade, translucency and matching the shade of the restoration with the neighboring teeth as well as the health of the surrounding soft tissue.

A uniform axial reduction of 1.2 mm is required on the entire facial surface. To achieve adequate reduction without encroaching on the pulp, the facial surface must be prepared in two planes corresponding roughly to the two planes present on the facial surface of an uncut tooth; marginal one third and the incisal inclination plane.

To provide the best aesthetics, incisal reduction of 2 mm is recommended. In posterior teeth, the suggested amount of reduction is 2 mm for functional cusps and 1.5 mm for non-functional cusps. It is advocated to place a shoulder facial margin to accommodate the thickness of both metal substructure and the porcelain. The thickness provides strength at the marginal area as well as aesthetics. For the palatal margin, reduction of 0.5 (chamfer metal margin) is proposed.

In posterior clinical scenarios were more strength and less aesthetics are needed or where the clinical crown height is minimal, a metal occlusal restoration could be made. The suggested amount of occlusal reduction for this restoration is 1.5 mm uniformly for both functional and non-functional cusps.
Lithium Disilicate Glass-Ceramic

The opalescence, translucency and light diffusion properties of lithium disilicate glass-ceramic provides excellent aesthetics, however, the inferior mechanical properties of the older generations of this material relative to porcelain-fused-to-metal or polycrystalline ceramics limited its application mostly to monolithic anterior single units or as a layering material for more robust substructures (17, 19). At the infancy of all ceramic materials, to compensate for the inferior mechanical properties, the amount of reduction needed for these materials were higher than PFM or metal cast restorations (20, 21). With the recent modifications made to this material, utilizing lithium disilicate glass-ceramic has been advocated for crowns (with the same or less tooth reduction than PFM), abutments for implant supported crowns as well as for screw retained implant supported crowns. The case selection for this application though should be thoroughly noted.

Preparations for this type of crown should be left as long as possible to give maximum support to the porcelain (2). An over-shortened preparation will create stress concentrations in the labiogingival area of the restoration. These areas of stress concentration can produce a so-called half-moon fracture in the labiogingival area of the restoration (22). An axial reduction of 1 mm followed by an occlusal/incisal reduction of 1.5 mm should be performed (23). A shoulder or chamfer of uniform width (approximately 1 mm) is advocated as a gingival finish line to provide a seat that resist forces directed from the incisal (23).

Polycrystalline Ceramic (Y-TZP)

Zirconia restorations in dentistry have gained popularity due to their biocompatibility and good mechanical properties. However, the notion that all ceramic materials need more tooth structure reduction is still existing.

To mask the opacity of this material, zirconia substructures are veneered with glass ceramics. The adhesion between the two materials makes these restorations weaker. In recent years, to
address this problem, monolithic zirconia restorations with higher aesthetics have been introduced to the field of dentistry. In addition to addressing the chipping and possibly dislodgement of the layered ceramic, the need for less tooth structure reduction to accommodate the monolithic restoration is clearly another significant advantage. In short, in areas with significant occlusal loads and minimal restorative space with demand for aesthetics, monolithic zirconia seems to be the optimum material of choice. Despite the numerous in vitro studies exhibiting superior results for monolithic zirconia restorations, there is a need for further in vivo studies with longer follow up periods to provide stronger evidence and more definitive conclusion.

The recommendations for zirconia preparations are currently controversial for different reasons. Firstly, at present there are different zirconia materials with different aesthetics and mechanical properties in dentistry. Secondly, zirconia is a more recent material, therefore, the existing studies conducted with various recommended preparations lack long-term follow ups.

Axial reduction of 0.5 to 1 mm with incisal or occlusal (for both functional and non-functional cusps) reduction of 1.5 mm is recommended for monolithic zirconia restorations.
Chapter 2 : Rational and Objectives

Statement of the Problem
As discussed earlier, the notion of need for more tooth structure reduction for all ceramic materials is still existing. What is more, there is no study conducted to either quantify the amount of tooth structure loss for different materials or showing if there is a significant difference between the amount of tooth-structure reductions for different materials. With the above-mentioned assumptions, the following research question and study objectives were formulated.

Research Question
The research question is that what is the amount of tooth reduction for three different crown materials of porcelain-fused-to-metal, lithium disilicate glass-ceramic and Y-TZP for teeth with three different morphologies.

Null Hypothesis
Base on the research question the following null hypothesis was defined for the study. The amount of tooth structure loss for full coverage preparations of different materials of zirconia, lithium disilicate glass-ceramic and porcelain-fused-to-metal in three different tooth morphologies of maxillary central incisor, first premolar and first molar is the same.

Study Objectives
The main objectives of this study were to:

1. Quantify the amount of tooth structure loss for particular preparations of three different
crown materials

2. Find the statistical significance among the amount of tooth structure reductions for three different crown preparations

Sample Size Calculation

Five maxillary left central incisor acrylic resin typodont teeth (Kilgore International, Inc., Coldwater, Michigan, USA) were individually weighed by the investigator before preparation with a highly precise scale (IBALANCE 211, My Weigh, Inc., Phoenix, Arizona, USA) with 0.0001-gram precision. The reduction protocol that was detailed in previous chapter for PFM crown preparation was utilized for preparing the teeth. The teeth were individually weighed after preparation with the same scale by the investigator. The percentage of tooth reduction for each tooth was calculated. The values for teeth before and after preparation, the percentage of weight reduction are given in table 1.

Table 1: Teeth 21 weight pre and post PFM preparing and percentage of tooth reduction

<table>
<thead>
<tr>
<th></th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor No. 1</td>
<td>1.0558</td>
<td>0.8059</td>
<td>23.66</td>
</tr>
<tr>
<td>Central incisor No. 2</td>
<td>1.0559</td>
<td>0.8084</td>
<td>23.43</td>
</tr>
<tr>
<td>Central incisor No. 3</td>
<td>1.0551</td>
<td>0.8167</td>
<td>22.59</td>
</tr>
<tr>
<td>Central incisor No. 4</td>
<td>1.0503</td>
<td>0.8002</td>
<td>23.81</td>
</tr>
<tr>
<td>Central incisor No. 5</td>
<td>1.0554</td>
<td>0.8192</td>
<td>22.38</td>
</tr>
</tbody>
</table>
The variance of the samples reduction percentages was calculated with the following formula:

\[ s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \]

Where \( n \) is the sample size (\( n=5 \)) and \( x\text{-bar} \) is the sample mean (\( \bar{x} : 23.17 \)).

**Variance (\( s^2 \)): 0.56**

**Formula for Sample Size Calculation**

The following formula was used to calculate the sample size \( n \):

\[ n = \frac{Z_{\alpha/2}^2 * s^2}{\text{MOE}^2} \]

where \( n \) is the sample size, \( Z_{\alpha/2} \) is the critical value of the Normal distribution at \( \alpha/2 \) (e.g. for a confidence level of 95%, \( \alpha \) is 0.05 and the critical value is 1.96), MOE is the margin of error, \( s^2 \) is the population variance.

The margin of error is the level of precision required. It is the range in which the true population mean is estimated to be. The confidence level is the probability that the margin of error contains the true mean. The higher the confidence level the more certain you can be that the interval contains the true mean.
Calculating the Sample Size

Variance \( (s^2) \): 0.56 \hspace{1cm} Z_{\alpha/2}: 1.96 \hspace{1cm} \text{MOE}: 5

\[
n = \frac{Z_{\alpha/2}^2 \cdot s^2}{\text{MOE}^2}
\]

\[
n = (1.96)^2 \cdot 0.56/5^2 = 0.08
\]

The calculated sample size with the margin of error of 5 and confidence level of 95% is 0.08. As the calculated sample size is showing a value higher than zero, it is rounded to the higher value of 1.

To increase the power of the study, the decision was to conduct the study with the sample size of 5 for each group. The calculated power of the study with the sample size of 5 is 0.8 which is a recommended power for such studies.
Chapter 3: Methods and Materials

Special Considerations

To reproduce the clinical environment, crown preparations were performed on Kilgore screw retained replacement teeth (Kilgore International, Inc., Coldwater, MI, USA) on Kilgore typodont. The typodont was then mounted on Kilgore DARWIN head with magnetic articulator. The upper and lower jaws of the typodont were held in place with locator pins and were magnetically attached to prevent changes in models’ occlusal contacts and interocclusal clearance. All the preparations were performed by the investigator for reliability.

For PFM crown preparation on different teeth morphologies, the guidelines followed were according to Prosthodontics reference books(2, 4). The preparations for zirconia and LDGC were performed according to the manufacturers’ guidelines and with consensus recommendations. Multiple PVS indices obtained before the preparation of every tooth, enabled us to evaluate the precise amount of reduction in each step as following (Figure 1). To add to precision and accuracy of the preparations, new burs were used for preparing every single tooth.

![Figure 1: A PVS index of a central incisor tooth](image)

To prevent melting of the acrylic resin teeth as well as for simulating clinical setting, water cooling handpieces were utilized for preparation of teeth. To nullify the effect of handpiece water absorption on samples’ weights, prior to conducting the study a left central acrylic resin tooth was kept in water for 24 hours period to recognize the effect of water on the weight of teeth. The weight change was less than 1% of the initial weight however, once the tooth was kept in room temperature for 48 hours, the weight was close to the initial weight within centigrams.
Consequently, all teeth after preparation were kept in room temperature for at least two days prior to weighing.

For each individual tooth, a minimum of three separate pieces of putty indices were fabricated prior to tooth preparation. These indices were utilized as the reference points for the mesial, mid-sagittal and distal reductions at different levels of incisal/occlusal and axial surfaces to ensure the highest possible clinical accuracy (figure 2). The armamentarium used for measuring the tooth reduction included color-coded probe, hatchets (1.0 mm and 1.2 mm blade width) and ball burnishers (1.0 mm, 1.5 mm and 2.00 mm tip). Further details are provided in Armamentarium section for preparation of each restorative material.

![Figure 2: A mid sagittal index utilized for checking the clearance of lingual aspect of a zirconia preparation](image)

**Porcelain-Fused-to-Metal Preparation**

**Armamentarium**

Laboratory knife with no. 25 blade

Silicone putty and accelerator

Handpieces (high speed and slow speed)

Flat-end parallel diamond [Brasseler 835.31.010]
Flat-end tapered diamond [Brasseler 847.31.012]

long needle diamond [Brasseler 859.31.10]

Tapered round-end diamond [Brasseler 851.31.012]

Tapered round-end diamond [Brasseler 851.31.014]

Fine-grit flat-end tapered diamond [Brasseler 837.31.012]

Flame-shaped diamond [Brasseler 368.31.023]

Single-end color-coded probe [Hu-Friedy pcp unc15]

Double-ended hatchet with blade width 1.2 mm and 1.5 mm [Brasseler HA15/16]

Double-ended hatchet with blade width 1.0 mm [Brasseler HA17/18]

Double-ended Ball burnisher with ball diameters of 1.0 mm and 2 mm [Brasseler BUR-42/6]

Double-ended Ball burnisher with ball diameters of 1.0 mm and 2 mm [Brasseler BUR-42/6]

Ball burnisher with ball diameter of 1.5 mm [Premier 424-1003028 27/29]

**Anterior Tooth Preparation Technique**

The preparation was initiated by placing depth-orientation grooves on the circumferential axial and incisal/occlusal surfaces with a flat-end tapered diamond as a guide for the amount of tooth structure that has to be removed. For the labial surface, we created two sets of grooves, one set parallel with the gingival half and one set parallel with the incisal half of surface.

2.0 mm incisal reduction was performed with the flat-end parallel diamond followed by utilizing a flat-end tapered diamond to reduce the entire facial surface for 1.2 mm. Using a long needle diamond the proximal contacts were opened and the labial reduction was carried around the labioproximal line angles to a point 1.0 mm lingual to the proximal contacts. From this point tooth
structure was gradually reduced to the shallower lingual wall (apical to cingulum) for 0.5 mm with tapered round-end diamond.

On the lingual surface, from incisal to the cingulum, 1.0 mm of clearance with opposing teeth was gained with the flame-shaped diamond bur.

To obtain an accurate and uniform reduction in all the samples the finish line was terminated at the gingival margin level.

Finally, all the axial/incisal walls and sharp line angles and margins were prepared with the fine-grit flat-end tapered diamond to smooth surfaces.

During the tooth preparation process, the amount of incisal and circumferential axial wall reduction was measured and checked concurrently with hatchets with 2.0 mm, 1.2 mm. The occlusal clearance was checked with the single-end color-coded probe and ball burnishers with tip diameter of 1.5 mm and 2.0 mm.

**Posterior Tooth Preparation Technique**

The same steps as mentioned above, were taken for preparation of the posterior teeth. For the conventional porcelain samples, occlusal reduction was completed with 2.0 mm and 1.5 mm reduction of the functional and non-functional cusps, respectively. Preparation of metal occlusal samples accounted for 1.5 mm reduction for both the functional and non-functional cusps.
Lithium Disilicate Glass-Ceramic Preparation

Armamentarium

Laboratory knife with no. 25 blade

Silicone putty and accelerator

Handpieces (high speed and slow speed)

Flat-end parallel diamond [Brasseler 835.31.010]

Flat-end tapered diamond [Brasseler 847.31.012]

Long needle diamond [Brasseler 859.31.10]

Tapered round-end diamond [Brasseler 851.31.012]

Tapered round-end diamond [Brasseler 851.31.014]

Fine-grit flat-end tapered diamond [Brasseler 837.31.012]

Flame-shaped diamond [Brasseler 368.31.023]

Single-end color-coded probe [Hu-Friedy pcp unc15]

Double-ended hatchet with blade width 1.2 mm and 1.5 mm [Brasseler HA15/16]

Double-ended hatchet with blade width 1.0 mm [Brasseler HA17/18]

Double-ended Ball burnisher with ball diameters of 1.0 mm and 2 mm [Brasseler BUR-42/6]

Ball burnisher with ball diameter of 1.5 mm [Premier 424-1003028 27/29]
Anterior Tooth Preparation Technique

Subsequent to placing depth-orientation grooves on the labial and incisal surfaces, the Incisal reduction of 1.5 mm was made with the flat-end parallel diamond. All the circumferential axial walls (buccal, lingual and proximal) were reduced with the flat-end tapered diamond to a depth of 1.0 mm. The reduction for the incisal edge to the cingulum aspect was performed with the flame-shaped diamond at 1.0 mm clearance from the opposing teeth. All the surfaces and sharp line angles were polished afterwards.

Posterior Tooth Preparation Technique

The very steps were taken for tooth preparation on posterior teeth except for the occlusal reduction for which, both functional and nonfunctional cusps were reduced 1.5 mm with a round-end parallel diamond.

During the tooth preparation process, the amount of incisal and circumferential axial wall reduction was measured and checked concurrently with hatchets with 1.5 mm, 1.0 mm. The occlusal clearance was checked with the single-end color-coded probe and ball burnisher with tip diameter of 1.5 mm.

Y-TZP Preparation

Armamentarium

Laboratory knife with no. 25 blade
Silicone putty and accelerator
Handpieces (high speed and slow speed)
Flat-end parallel diamond [Brasseler 835.31.010]

long needle diamond [Brasseler 859.31.10]

Tapered round-end diamond [Brasseler 851.31.012]

Tapered round-end diamond [Brasseler 851.31.014]

Fine-grit round-end tapered diamond [Brasseler 856.31.012]

Flame-shaped diamond [Brasseler 368.31.023]

Single-end color-coded probe [Hu-Friedy pcp unc15]

Double-ended hatchet with 1.2 mm and 1.5 mm blade width [Brasseler HA15/16]

Double-ended hatchet with blade width 1.0 mm [Brasseler HA17/18]

Ball burnisher with ball diameter of 1.5 mm [Premier 424-1003028 27/29]

Anterior Tooth Preparation Technique

Following placement of depth-orientation grooves on the labial and incisal surfaces, the incisal edge was reduced for 1.5 mm with the flat-end tapered diamond. All the axial walls of buccal, lingual and proximal were reduced with the round-end tapered diamond to a depth of approximately 0.8 mm. The reduction for the incisal edge to the cingulum aspect was made with the flame-shaped diamond for about 0.8 mm clearance from the opposing teeth.

Posterior Tooth Preparation Technique

Similar steps as mentioned above were taken for tooth preparation on posterior teeth except for the occlusal reduction for which, both functional and nonfunctional cusps were reduced for 1.5 mm with the round-end parallel diamond.
During the tooth preparation process, the amount of incisal and circumferential axial wall reduction was measured and checked concurrently with hatchets with 1.5 mm, 0.8 mm. The occlusal clearance was checked with the single-end color-coded probe and ball burnisher with tip diameter of 1.5 mm.

The prepared teeth of different tooth morphologies are presented in figures 3-5.

Figure 3: Tooth 21 prepared for different restorations. From left to right: zirconia, lithium disilicate glass-ceramic and PFM

Figure 4: Tooth 24 prepared for different restorations. From left to right: zirconia, lithium disilicate glass-ceramic and PFM

Figure 5: Tooth 26 prepared for different restorations. From left to right: zirconia, lithium disilicate glass-ceramic and PFM
Calculating the Amount of Tooth Structure Loss

The initial weight prior to preparation and the weight after the preparation was measured with a precise scale. All the weight measurements and recordings were performed by the investigator for reliability. The amount of net weight-loss after preparation as well as the percentage of the amount of tooth structure loss for every single tooth were subsequently calculated. The mean and the standard deviation for weight-loss in grams and weight-loss percentage was also determined for comparison and statistical analyses.
Chapter 4 : Results

Summary

This section presents the results of tooth structure reduction for different materials and tooth morphologies.

Descriptive statistics were used to summarize the results of all groups. A one-way ANOVA was conducted to figure out if there is a statistical significance in the amount of tooth reduction for different materials. The post-hoc Tukey test was conducted to realize what groups show statistical significance compared to each other. The one-way ANOVA with post-hoc Tukey test was conducted for both the percentage of weight loss (that was calculated by dividing the weight of the amount of tooth reduction in gram over the initial weight of the tooth prior to preparation) as well as for the amount of weight loss per gram. The results of the former and the latter analyses are coinciding.

For teeth 21 and 24, there was no statistical significant difference between the mean tooth structure loss for PFM and lithium disilicate glass-ceramic restorations at P<0.05; however, there was a statistical significant difference between the amount of tooth structure loss for PFM and lithium disilicate glass-ceramic with Y-TZP (p<.000).

The result of one-way ANOVA test for tooth 26 showed the same results. There was no statistical significant difference between the amount of tooth structure loss for three groups of conventional PFM, PFM with metal occlusal and lithium disilicate glass-ceramic at P<0.05. All three above mentioned groups showed a statistical significant difference in mean tooth structure loss compared with Y-TZP (p<.000).

Comparisons and interpretation of the results and statistical analysis will be presented in the “Discussion” section.
Data Analysis

A total of 50 teeth of three different morphologies were prepared for the study. Teeth 21 and 24 consisted of three groups of PFM, lithium disilicate glass-ceramic and zirconia and each group included five samples (i.e. total of 2 x 3 x 5=30 teeth for these groups).

Teeth 26 also consisted of three above mentioned groups plus one more group for PFM with metal occlusal preparation. Again, each group included five samples (i.e. 4 X 5=20 teeth for this group). This produced a whole sample of 50 teeth for the study.

The Statistical Package for Social Sciences [SPSS] version 20.0 (SPSS®, Chicago, Ill, USA) was used for data management and analysis. Descriptive statistics were used to exhibit the mean for each group as well as maximum and minimum percentage of tooth structure loss in each group.

Consequently, between the groups one-way ANOVA with post-hoc Tukey statistical test was conducted for each individual tooth morphology to find if there is a statistical significance between the amount of tooth structure reduction for different restorative materials. Post Hoc Tukey analysis was performed to show what groups exhibited statistical significance among themselves.

Amount of Tooth Structure Loss of the Study Samples

The initial weight prior to preparation, the weight after the preparation, the amount of weight that was lost after preparation as well as the percentage of the amount of tooth structure loss for teeth 21, 24 and 26 are subsequently shown in detail in Tables 1-10. The mean and the standard deviation for weight loss in grams and weight loss percentage is also provided at the end of the columns.

The group with the least amount of tooth structure reduction was 26 zirconia preparation (mean= 17.89%).
The group that exhibited the most amount of tooth structure reduction between all the groups was 24 lithium disilicate glass-ceramic preparation (mean= 24.24%).

Table 2: Pre and post weight as well as percentage of weight loss for tooth 21 for PFM

<table>
<thead>
<tr>
<th>N=5</th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor No. 1</td>
<td>1.0558</td>
<td>0.8059</td>
<td>0.2499</td>
<td>23.66</td>
</tr>
<tr>
<td>Central incisor No. 2</td>
<td>1.0559</td>
<td>0.8084</td>
<td>0.2475</td>
<td>23.43</td>
</tr>
<tr>
<td>Central incisor No. 3</td>
<td>1.0551</td>
<td>0.8167</td>
<td>0.2384</td>
<td>22.59</td>
</tr>
<tr>
<td>Central incisor No. 4</td>
<td>1.0503</td>
<td>0.8002</td>
<td>0.2501</td>
<td>23.81</td>
</tr>
<tr>
<td>Central incisor No. 5</td>
<td>1.0554</td>
<td>0.8192</td>
<td>0.2362</td>
<td>22.38</td>
</tr>
</tbody>
</table>

Mean= 0.2444
SD=0.0066
Mean= 23.17
SD=0.6476

The minimum percentage of tooth structure loss for this group was 22.38% and the maximum percentage of tooth structure loss was 23.81%. The mean amount of tooth structure loss for tooth 21 prepared for PFM was 23.17%.
Table 3: Pre and post weight as well as percentage of weight loss for tooth 21 for lithium disilicate glass-ceramic

<table>
<thead>
<tr>
<th></th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor No. 1</td>
<td>1.0517</td>
<td>0.8115</td>
<td>0.2402</td>
<td>22.83</td>
</tr>
<tr>
<td>Central incisor No. 2</td>
<td>1.0596</td>
<td>0.812</td>
<td>0.2476</td>
<td>23.36</td>
</tr>
<tr>
<td>Central incisor No. 3</td>
<td>1.057</td>
<td>0.8298</td>
<td>0.2272</td>
<td>21.49</td>
</tr>
<tr>
<td>Central incisor No. 4</td>
<td>1.0594</td>
<td>0.821</td>
<td>0.2384</td>
<td>22.50</td>
</tr>
<tr>
<td>Central incisor No. 5</td>
<td>1.0571</td>
<td>0.8206</td>
<td>0.2365</td>
<td>22.37</td>
</tr>
</tbody>
</table>

Mean = 0.2379
SD = 0.0073

The minimum percentage of tooth structure loss was 21.49% and the maximum percentage of tooth structure loss was 23.36%. The mean amount of tooth structure loss for tooth 21 prepared for lithium disilicate glass-ceramic was 22.51%. This is 0.66% less than PFM preparations.
Table 4: Pre and post weight as well as percentage of weight loss for tooth 21 for zirconia

<table>
<thead>
<tr>
<th></th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor No. 1</td>
<td>1.0579</td>
<td>0.8545</td>
<td>0.2034</td>
<td>19.22</td>
</tr>
<tr>
<td>Central incisor No. 2</td>
<td>1.0627</td>
<td>0.8472</td>
<td>0.2155</td>
<td>20.27</td>
</tr>
<tr>
<td>Central incisor No. 3</td>
<td>1.0597</td>
<td>0.8406</td>
<td>0.2191</td>
<td>20.67</td>
</tr>
<tr>
<td>Central incisor No. 4</td>
<td>1.0584</td>
<td>0.8589</td>
<td>0.1995</td>
<td>18.84</td>
</tr>
<tr>
<td>Central incisor No. 5</td>
<td>1.0568</td>
<td>0.8461</td>
<td>0.2107</td>
<td>19.93</td>
</tr>
<tr>
<td>Mean= 0.2096</td>
<td>Mean= 19.78</td>
<td>SD=0.0081</td>
<td>SD=0.7502</td>
<td></td>
</tr>
</tbody>
</table>

The minimum percentage of tooth structure loss was 19.22% and the maximum percentage of tooth structure loss was 20.67%. The mean amount of tooth structure loss for tooth 21 prepared for zirconia was 19.78%. This is the least amount of reduction compared with the latter groups. It is 2.73% less than lithium disilicate glass-ceramic and 3.39% less than PFM preparations.
Table 5: Pre and post weight as well as percentage of weight loss for tooth 24 for PFM

<table>
<thead>
<tr>
<th>N=5</th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First premolar No. 1</td>
<td>0.9962</td>
<td>0.7655</td>
<td>0.2307</td>
<td>23.15</td>
</tr>
<tr>
<td>First premolar No. 2</td>
<td>0.9978</td>
<td>0.7639</td>
<td>0.2339</td>
<td>23.44</td>
</tr>
<tr>
<td>First premolar No. 3</td>
<td>0.9978</td>
<td>0.762</td>
<td>0.2358</td>
<td>23.63</td>
</tr>
<tr>
<td>First premolar No. 4</td>
<td>0.9932</td>
<td>0.7615</td>
<td>0.2317</td>
<td>23.32</td>
</tr>
<tr>
<td>First premolar No. 5</td>
<td>0.9952</td>
<td>0.7544</td>
<td>0.2408</td>
<td>24.19</td>
</tr>
</tbody>
</table>

Mean= 0.2345  SD=0.0039  Mean= 23.54  SD=0.4002

The minimum percentage of tooth structure loss was 23.15% and the maximum percentage of tooth structure loss was 24.19%. The mean amount of tooth structure loss for tooth 24 prepared for PFM was 23.54% which is very close to the mean amount of tooth reduction for tooth 21 for PFM that was 23.17%.
Table 6: Pre and post weight as well as percentage of weight loss for tooth 24 for lithium disilicate glass-ceramic

<table>
<thead>
<tr>
<th>N=5</th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First premolar No. 1</td>
<td>0.9962</td>
<td>0.7586</td>
<td>0.2376</td>
<td>23.85</td>
</tr>
<tr>
<td>First premolar No. 2</td>
<td>0.9968</td>
<td>0.765</td>
<td>0.2318</td>
<td>23.25</td>
</tr>
<tr>
<td>First premolar No. 3</td>
<td>0.9969</td>
<td>0.7548</td>
<td>0.2421</td>
<td>24.28</td>
</tr>
<tr>
<td>First premolar No. 4</td>
<td>0.9983</td>
<td>0.7466</td>
<td>0.2517</td>
<td>25.21</td>
</tr>
<tr>
<td>First premolar No. 5</td>
<td>1.0006</td>
<td>0.754</td>
<td>0.2466</td>
<td>24.64</td>
</tr>
</tbody>
</table>

Mean= 0.2419 Mean= 24.24  
SD=0.0077 SD=0.7474

The minimum percentage of tooth structure loss was 23.25% and the maximum percentage of tooth structure loss was 25.21%. The mean was 24.24% that is 0.7% more tooth structure loss than PFM for the same tooth morphology. The mean amount of tooth structure loss for tooth 24 prepared for lithium disilicate glass-ceramic was 24.24% which is 1.7% more than the mean amount of tooth reduction for tooth 21 for the same material.
Table 7: Pre and post weight as well as percentage of weight loss for tooth 24 for zirconia

<table>
<thead>
<tr>
<th>N=5</th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First premolar No. 1</td>
<td>0.9993</td>
<td>0.8071</td>
<td>0.1922</td>
<td>19.23</td>
</tr>
<tr>
<td>First premolar No. 2</td>
<td>0.997</td>
<td>0.779</td>
<td>0.218</td>
<td>21.86</td>
</tr>
<tr>
<td>First premolar No. 3</td>
<td>0.9967</td>
<td>0.7809</td>
<td>0.2158</td>
<td>21.65</td>
</tr>
<tr>
<td>First premolar No. 4</td>
<td>0.9944</td>
<td>0.7942</td>
<td>0.2002</td>
<td>20.13</td>
</tr>
<tr>
<td>First premolar No. 5</td>
<td>0.9973</td>
<td>0.7938</td>
<td>0.2035</td>
<td>20.40</td>
</tr>
<tr>
<td>Mean= 0.2059</td>
<td>Mean= 20.65</td>
<td>SD=0.0108</td>
<td>SD=1.0969</td>
<td></td>
</tr>
</tbody>
</table>

The minimum percentage of tooth structure loss was 19.23% and the maximum percentage of tooth structure loss was 21.86%. The mean was 20.65. This 3.59% less tooth structure loss than lithium disilicate glass-ceramic and 2.89% less than PFM for the same tooth morphology. The mean amount of tooth structure loss for tooth 24 prepared for zirconia is 0.87% more than the mean amount of tooth reduction for tooth 21 for the same material.
Table 8: Pre and post weight as well as percentage of weight loss for tooth 26 for conventional PFM

<table>
<thead>
<tr>
<th></th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First molar No. 1</td>
<td>1.9616</td>
<td>1.5044</td>
<td>0.4572</td>
<td>23.30</td>
</tr>
<tr>
<td>First molar No. 2</td>
<td>1.9728</td>
<td>1.493</td>
<td>0.4798</td>
<td>24.32</td>
</tr>
<tr>
<td>First molar No. 3</td>
<td>1.9525</td>
<td>1.5173</td>
<td>0.4352</td>
<td>22.28</td>
</tr>
<tr>
<td>First molar No. 4</td>
<td>1.9508</td>
<td>1.4936</td>
<td>0.4572</td>
<td>23.43</td>
</tr>
<tr>
<td>First molar No. 5</td>
<td>1.9602</td>
<td>1.5307</td>
<td>0.4295</td>
<td>21.91</td>
</tr>
<tr>
<td>Mean= 0.4517</td>
<td>Mean= 23.04</td>
<td>SD=0.0200</td>
<td>SD=0.9633</td>
<td></td>
</tr>
</tbody>
</table>

The minimum percentage of tooth structure loss was 21.91% and the maximum percentage of tooth structure loss was 24.32%. The mean was 23.04%. The mean amount of tooth structure loss for tooth 26 prepared for conventional PFM is 0.13% less than the mean amount of tooth reduction for tooth 21 and 0.5% less than the mean amount of tooth reduction for tooth 24 for the same material.
Table 9: Pre and post weight as well as percentage of weight loss for tooth 26 for metal occlusal PFM

<table>
<thead>
<tr>
<th></th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First molar No. 1</td>
<td>1.9438</td>
<td>1.539</td>
<td>0.4048</td>
<td>20.82</td>
</tr>
<tr>
<td>First molar No. 2</td>
<td>1.9528</td>
<td>1.5133</td>
<td>0.4395</td>
<td>22.50</td>
</tr>
<tr>
<td>First molar No. 3</td>
<td>1.9518</td>
<td>1.5152</td>
<td>0.4366</td>
<td>22.36</td>
</tr>
<tr>
<td>First molar No. 4</td>
<td>1.9536</td>
<td>1.5208</td>
<td>0.4328</td>
<td>22.15</td>
</tr>
<tr>
<td>First molar No. 5</td>
<td>1.9594</td>
<td>1.557</td>
<td>0.4024</td>
<td>20.53</td>
</tr>
</tbody>
</table>

Mean= 0.4232
SD=0.0180
Mean= 21.67
SD=0.9243

The minimum percentage of tooth structure loss was 20.53% and the maximum percentage of tooth structure loss was 22.50%. The mean was 21.67. This 1.37% less tooth structure loss than conventional PFM for the same tooth morphology.
Table 10: Pre and post weight as well as percentage of weight loss for tooth 26 for lithium disilicate glass-ceramic

<table>
<thead>
<tr>
<th>N=5</th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First molar No. 1</td>
<td>1.9555</td>
<td>1.5344</td>
<td>0.4211</td>
<td>21.53</td>
</tr>
<tr>
<td>First molar No. 2</td>
<td>1.9536</td>
<td>1.5478</td>
<td>0.4058</td>
<td>20.77</td>
</tr>
<tr>
<td>First molar No. 3</td>
<td>1.9543</td>
<td>1.4934</td>
<td>0.4609</td>
<td>23.58</td>
</tr>
<tr>
<td>First molar No. 4</td>
<td>1.9543</td>
<td>1.5657</td>
<td>0.3886</td>
<td>19.88</td>
</tr>
<tr>
<td>First molar No. 5</td>
<td>1.9511</td>
<td>1.5095</td>
<td>0.4416</td>
<td>22.63</td>
</tr>
</tbody>
</table>

Mean= 0.4236 Mean= 21.89
SD=0.0285 SD=1.4665

The minimum percentage of tooth structure loss was 19.88% and the maximum percentage of tooth structure loss was 23.58%. The mean was 21.89. This is 1.15% less tooth structure loss than conventional PFM and 0.22% more than PFM with occlusal for the same tooth morphology.

The mean amount of tooth structure loss for tooth 26 prepared for lithium disilicate glass-ceramic is 0.62% less than the mean amount of tooth reduction for teeth 21 for the same material.

The mean amount of tooth structure loss for tooth 26 prepared for lithium disilicate glass-ceramic is 2.35% more for teeth 24 for the same material.
Table 11: Pre and post weight as well as percentage of weight loss for tooth 26 for zirconia

<table>
<thead>
<tr>
<th>N=5</th>
<th>Pre-preparation weight (gram)</th>
<th>Post preparation weight (gram)</th>
<th>Weight loss (gram)</th>
<th>Weight loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First molar No. 1</td>
<td>1.9521</td>
<td>1.5905</td>
<td>0.3616</td>
<td>18.52</td>
</tr>
<tr>
<td>First molar No. 2</td>
<td>1.9544</td>
<td>1.5796</td>
<td>0.3748</td>
<td>19.17</td>
</tr>
<tr>
<td>First molar No. 3</td>
<td>1.9564</td>
<td>1.6223</td>
<td>0.3341</td>
<td>17.07</td>
</tr>
<tr>
<td>First molar No. 4</td>
<td>1.9708</td>
<td>1.6295</td>
<td>0.3413</td>
<td>17.31</td>
</tr>
<tr>
<td>First molar No. 5</td>
<td>1.9548</td>
<td>1.6148</td>
<td>0.34</td>
<td>17.39</td>
</tr>
</tbody>
</table>

Mean= 0.0350  Mean=17.89
SD= 0.0171  SD=0.9074

The minimum percentage of tooth structure loss was 17.07% and the maximum percentage of tooth structure loss was 19.17%. The mean was 17.89. This is the least amount of reduction between all the groups.

This 4.0% less tooth structure loss than lithium disilicate glass-ceramic, 3.78% less than PFM with metal occlusal and 5.15% less than conventional PFM for the same tooth morphology. The mean amount of tooth structure loss for tooth 26 prepared for zirconia is 1.89% less than the mean amount of tooth reduction for tooth 21 and 2.76% less than the mean amount of tooth reduction for tooth 24 for the same material.
One-Way ANOVA with Post-Hoc Tukey Test Results

For each tooth morphology, One-way ANOVA with post-hoc Tukey test was conducted for both the calculated percentage of tooth structure reduction as well as for the net weight loss in grams after preparation (Tables 12-17).

For tooth 21, the one-way ANOVA with post-hoc Tukey analysis showed statistical significance for the amount of tooth reduction for zirconia compared with PFM and lithium disilicate glass-ceramic (p<0.05).

There was no statistical significance between the amount of tooth reduction for PFM and lithium disilicate glass-ceramic for tooth 21 (p>0.05).

Table 12: One-way ANOVA with post-hoc Tukey test results showing the statistical significance and corresponding p values for the percentages of tooth structure loss of three different groups of PFM, lithium disilicate glass-ceramic and zirconia for tooth 21 (p<0.05)

<table>
<thead>
<tr>
<th>Tooth 21</th>
<th>PFM</th>
<th>Lithium disilicate glass-ceramic</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFM</td>
<td>N/A</td>
<td>No significance</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p=0.32</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Lithium disilicate glass-ceramic</td>
<td>No significance</td>
<td>N/A</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p=0.32</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Statistical significant</td>
<td>Statistical significant</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p&lt;.05</td>
<td>p&lt;.05</td>
<td></td>
</tr>
</tbody>
</table>
Table 13: One-way ANOVA with post-hoc Tukey test results showing the statistical significance and corresponding p values for the tooth structure loss net weight of three different groups of PFM, lithium disilicate glass-ceramic and zirconia for tooth 21 (p<0.05)

<table>
<thead>
<tr>
<th>Tooth 21</th>
<th>PFM</th>
<th>Lithium disilicate glass-ceramic</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFM</td>
<td>N/A</td>
<td>No significance p=0.212</td>
<td>Statistical significant p&lt;0.052</td>
</tr>
<tr>
<td>Lithium disilicate glass-ceramic</td>
<td>No significance p=0.212</td>
<td>N/A</td>
<td>Statistical significant p=0.04</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Statistical significant p&lt;0.052</td>
<td>Statistical significant p=0.049</td>
<td>N/A</td>
</tr>
</tbody>
</table>

For tooth 24, the one-way ANOVA test with post-hoc Tukey analysis for both the percentages and net weight of tooth structure loss showed statistical significance for the amount of tooth reduction for zirconia compared with PFM and lithium disilicate glass-ceramic (p<0.05).

There was no statistical significance between the amount of tooth reduction for PFM and lithium disilicate glass-ceramic for tooth 24 (p>0.05).
Table 14: One-way ANOVA with post-hoc Tukey test results showing the statistical significance and corresponding p values for the percentages of tooth structure loss of three different groups of conventional PFM, lithium disilicate glass-ceramic and zirconia for tooth 24 (p<0.05)

<table>
<thead>
<tr>
<th>Tooth 24</th>
<th>PFM</th>
<th>Lithium disilicate glass-ceramic</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFM</td>
<td>N/A</td>
<td>No significance p=0.38</td>
<td>Statistical significance p&lt;.05</td>
</tr>
<tr>
<td>Lithium disilicate glass-ceramic</td>
<td>No significance p=0.38</td>
<td>N/A</td>
<td>Statistical significance p&lt;.05</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Statistical significance p&lt;.05</td>
<td>Statistical significance p&lt;.05</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Table 15: One-way ANOVA with post-hoc Tukey test results showing the statistical significance and corresponding p values for the net weight of tooth structure loss of three different groups of conventional PFM, lithium disilicate glass-ceramic and zirconia for tooth 24 (p<0.05)

<table>
<thead>
<tr>
<th>Tooth 24</th>
<th>PFM</th>
<th>Lithium disilicate glass-ceramic</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFM</td>
<td>N/A</td>
<td>No significance</td>
<td>Statistical significance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p=0.34</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Lithium disilicate glass-ceramic</td>
<td>No significance</td>
<td>N/A</td>
<td>Statistical significance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p=0.34</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Statistical significance</td>
<td>Statistical significance</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p&lt;.05</td>
<td></td>
</tr>
</tbody>
</table>

For tooth 26, the one-way ANOVA with post-hoc Tukey analysis for both the percentages and net weight of tooth structure loss showed statistically significant difference in mean tooth reduction for zirconia compared with conventional PFM, PFM with metal occlusal and lithium disilicate glass-ceramic (p<0.05).

There was no statistically significant difference between mean amount of tooth reduction for the other three groups for tooth 26 (p>0.05).
Table 16: One-way ANOVA with post-hoc Tukey test results showing the statistical significance and corresponding p values for the percentages of tooth structure loss of four different groups of conventional PFM, PFM with metal occlusal, lithium disilicate glass-ceramic and zirconia for tooth 26 (p<0.05)

<table>
<thead>
<tr>
<th>Tooth 26</th>
<th>Conventional PFM</th>
<th>PFM with metal occlusal</th>
<th>Lithium disilicate glass-ceramic</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional PFM</td>
<td>N/A</td>
<td>No significance</td>
<td>No significance</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p=0.23</td>
<td>p=0.23</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>PFM with metal occlusal</td>
<td>No significance</td>
<td>N/A</td>
<td>No significance</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td>p=0.23</td>
<td></td>
<td>p=1.00</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Lithium disilicate glass-ceramic</td>
<td>No significance</td>
<td>No significance</td>
<td>N/A</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td>p=0.23</td>
<td>p=1.00</td>
<td></td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Statistical significant</td>
<td>Statistical significant</td>
<td>Statistical significant</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p&lt;.05</td>
<td>p&lt;.05</td>
<td>p&lt;.05</td>
<td></td>
</tr>
</tbody>
</table>
Table 17: One-way ANOVA with post-hoc Tukey test results showing the statistical significance and corresponding p values for the net weight of tooth structure loss of four different groups of conventional PFM, PFM with metal occlusal, lithium disilicate glass-ceramic and zirconia for tooth 26 (p<0.05)

<table>
<thead>
<tr>
<th>Tooth 26</th>
<th>Conventional PFM</th>
<th>PFM with metal occlusal</th>
<th>Lithium disilicate glass-ceramic</th>
<th>Zirconia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional PFM</td>
<td>N/A</td>
<td>No significance</td>
<td>No significance</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p=0.19</td>
<td>p=0.20</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>PFM with metal occlusal</td>
<td>No significance</td>
<td>N/A</td>
<td>No significance</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td>p=0.19</td>
<td>p=1.00</td>
<td>p=1.00</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Lithium disilicate glass-ceramic</td>
<td>No significance</td>
<td>No significance</td>
<td>N/A</td>
<td>Statistical significant</td>
</tr>
<tr>
<td></td>
<td>p=0.20</td>
<td>p=1.00</td>
<td></td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Zirconia</td>
<td>Statistical significant</td>
<td>Statistical significant</td>
<td>Statistical significant</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>p&lt;.05</td>
<td>p&lt;.05</td>
<td>p&lt;.05</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5 : Discussion

Significance of the Study

This study is the first research that is providing an answer to the fundamental question of what material requires the least amount of tooth structure reduction for full coverage restorations of anterior and posterior teeth. It also exhibits the volume quantity of the of tooth structure loss for preparation of three different materials of PFM, lithium disilicate glass-ceramic and zirconia for teeth of different morphologies.

Methods for Calculation of the Amount of Tooth Structure Loss

Different approaches that could possibly be taken pertaining to the calculation of the amount of tooth structure loss were considered for the study.

Initially, the idea of using a 3-dimensional scanner was explored. A 3-dimensional scan of each tooth before preparation will be made. The teeth will be prepared following the standard recommendations of preparations. Then the prepared tooth will be rescanned. The two scan files will be superimposed over each other and the amount of volume loss that will be corresponding to tooth structure loss will be calculated utilizing a software that maps the volume reduction.

The other path that was looked at was utilizing a micro CT-scan. A micro CT-scan of the tooth prior to preparation will be made. The tooth will be prepared according to the standard preparation guidelines. A micro CT-scan will be taken of the prepared tooth. The micro CT-scan will calculate the volume between the two scans with the corresponding software.

Exploring the former idea, it was realized that the existing dental software packages in the market only provide a two-dimensional superimposition that will not serve the purpose for our study in which there is a need for a 3-dimensional superimposition.
The latter methodology was not followed either because of the limited accessibility to the micro CT-scan, as well as the high cost of using this technology.

The last idea sought for calculation of the amount of tooth structure loss was 3-dimensional scanning of a tooth and then modifying the tooth following the standard recommendations of preparation on a computer utilizing a specialized engineering software. The outcome would be the most precise and accurate result. What is more, there was no need for actual clinical preparation of teeth.

So far, a milling system for preparing the teeth intra-orally has not been developed. Therefore, preparing the teeth with handpieces and burs in a clinical setting remains the gold standard of care for this procedure. Therefore, the discussed method, will not be a good simulation of actual clinical setting despite the accuracy and precision of it. Consequently, the study was designed in a manner to simulate the clinical setting as much as possible.

Utilizing acrylic resin typodont teeth for the study and calculating the amount of tooth structure loss by precisely weighing the tooth pre preparation, then preparing the teeth in a simulated clinical setting and re-weighing prepared teeth post preparation was the methodology selected for this study.

It could be argued that using natural extracted teeth in the study will provide more accurate results as it will be a closer simulation of a clinical setting. There were a few concerns with this approach. Firstly, the heterogeneity of tooth tissues make it impossible to correlate the amount of weight loss with the amount of volume loss. The density and weight of enamel and dentin are different. Therefore, the gravimetric measurement of weight loss will not precisely co-relate with the volume loss.

Secondly, extracted teeth might have various morphological deviations such as various size and form of crowns, existing caries and the size and extension of the pulp chambers that makes the intergroup comparison difficult.

The homogeneity of the structure of the acrylic resin teeth allows following a standardized preparation technique. It also made the precise co-relation of the gravimetric measurements
with the amount of volume loss possible. This homogeneity also made the intergroup comparisons possible as all the teeth at the baseline shared the same anatomical structure and weight. As shown in tables 2-11, the initial weight of each tooth morphology was similar within centigram.

Pertaining to the weight-change measurements due to the water exposure, it should be noted that the outer layer of acrylic resin teeth are smooth and polished. Consequently the surface energy is less and the contact-angle with water is possibly way more than the rough surface of a prepared crown. That said, the amount of time the actual study teeth were exposed to the handpiece water was significantly less than the 24 hours interval used to examine the effect of water on the samples.

Mathematical Equation for Measuring the Structure Loss

The equation used for calculating the amount of tooth structure loss was as followed:

a) each tooth was weighed to precision of 0.0001 gram
b) each tooth was prepared following the recommended preparations
c) each tooth was re-weighed after 48 hours of being kept in room temperature after preparation to precision of 0.0001 gram
d) the percentage of weight loss was calculated by dividing the net weight loss over the initial weight multiply by 100

Another approach for measuring the amount of tooth reduction could be using the mean of weights for both prepared and unprepared teeth per group rather than every single tooth. This approach is not as precise as the approach taken in our study specifically if the value for variance of weights is higher within groups.

It is crucial to note that the percentage of reduction exhibits the percentage of reduction from the whole tooth and not only from the coronal aspect of tooth. To calculate the percentage of
reduction of the coronal aspect, the root of each tooth should be cut out and weighed. Then the measured weight should be subtracted from both pre and post measured weights and the calculation should be carried out with these measured values.

Providing the percentage of reduction of the crown could be a better approach to take. It makes it more comprehensible for readers to know how much of tooth volume is reduced from the crown rather than from the whole tooth. The reason this was not pursued was that precisely cutting the root aspect poses some challenges. Firstly, cutting the root with a thin bur will result in cutting debridement that will be hard if not impossible to include in the weight measurement. Cutting the root with a regular precision hot cutter will also result in some melted material waste. Secondly, the irregular marginal aspect of a crown makes the precision of the incision very challenging for different crowns.

Statistical Analyses

One-way ANOVA with post-hoc Tukey test was used to compare the means of each tooth structure loss as well as for comparing the net weight loss of each tooth.

The former analysis seem to provide a more accurate answer because as previously mentioned, the percentage of reduction has been calculated by dividing the net weight loss over the initial weight. This equation involves both the initial weight of each tooth before preparation as well as the weight loss after preparation however for the latter analysis, only the weight loss of each tooth is used without considering the fact that the initial weight of the teeth were slightly different. This might bring some inaccuracy to the statistical analyses. That being said, despite the potential inaccuracy of the latter analysis the results of both one-way ANOVA with post-hoc Tukey analyses are in agreement.
Amount of Tooth Structure Loss for Different Materials

Yttria stabilized tetragonal zirconia polycrystalline is the material that saved most amount of tooth structure compared with both PFM and lithium disilicate glass-ceramic. The results of tooth structure loss for different materials for teeth of different morphologies are given in tables 2-11. The mean amount of tooth structure loss for different preparation designs of different teeth morphologies increased in the following order (Figure 6):

26 zirconia; 17.89% (SD=0.9074)
21 zirconia; 19.78% (SD=0.7502)
24 zirconia; 20.65% (SD=1.0969)
26 metal occlusal PFM; 21.67% (SD=0.9243)
26 lithium disilicate glass-ceramic; 21.89% (SD=1.4665)
21 lithium disilicate glass-ceramic; 22.51% (SD=0.6864)
26 PFM; 23.04% (SD=0.9633)
21 PFM; 23.17% (SD=0.6476)
24 PFM; 23.54% (SD=0.4002)
24 lithium disilicate glass-ceramic; 24.24% (SD=0.7474)
Figure 6: Amount of tooth structure loss in percentage from the least to the most. Y-TZP (zirconia), m.o. PFM (metal occlusal porcelain-fused-to-metal), LDGC (lithium disilicate glass-ceramic) and PFM (conventional porcelain-fused-to-metal)

The least amount of structure loss was for tooth 26 zirconia preparation (i.e. 17.89%, SD= 0.9074). The most amount of tooth structure loss was for tooth 24 lithium disilicate glass-ceramic preparation (i.e. 24.24%, SD=0.7474). This more than 6% of difference in structural preservation.

These results show that for a zirconia crown on average, about 3.8% of more tooth structure will be saved compared to a conventional PFM crown. The amount of tooth preservation for zirconia versus lithium disilicate glass-ceramic is slightly less than the amount for conventional PFM. About 3.4% of tooth structure can be saved for a zirconia crown compared to a lithium disilicate glass-ceramic crown on average.

The difference between the volume of tooth difference between lithium disilicate glass-ceramic and conventional PFM is as little as 0.4%.
Except for tooth 24 lithium disilicate glass-ceramic preparation that showed the most amount of reduction (24.24%, SD= 0.7474), conventional PFM preparation exhibit the highest amount of tooth structure loss.

Comparing the three preparation groups of PFM, lithium disilicate glass-ceramic and zirconia, in each group, tooth 26 show the least amount of reduction and 24 show the most amount of reduction. The more removal of tooth structure from tooth 24 might be influenced by the specific morphology of the coronal aspect of tooth 24.

Tooth 24 lithium disilicate glass-ceramic preparation showed the highest amount of tooth structure removal (24.24%, SD= 0.7474) in total. Once more, the specific morphology of the coronal aspect of tooth 24 can be the reason behind this significant reduction. A uniform circumferential axial reduction of 1 mm for this preparation resulted in more tooth structure loss compared to 1.2 mm of axial reduction for PFM with gradually decreasing to 0.5 mm margin at the lingual aspect for this specific tooth morphology.

At face-value, the results show more tooth structure preservation with metal occlusal preparation of 26 than lithium disilicate glass-ceramic and conventional PFM preparations. That said, this difference is not statistically significant.

The statistical analyses performed with percentage of tooth structure loss as well as with net weight of tooth structure loss clearly showed that the amount of tooth reduced for zirconia preparation is statistically significant compared to the amount of tooth reduced for PFM and lithium disilicate glass-ceramic preparations. Lithium disilicate glass-ceramic and PFM preparations however, did not exhibit a statistical significant difference regarding the amount of tooth loss after preparation. Although it appears that PFM preparations are more aggressive in terms of tooth structure loss compared with lithium disilicate glass-ceramic preparations, apparently providing a lingual metal margin of 0.5 mm for PFM crowns makes the overall tooth structure loss for these two preparations statistically insignificant.

There are three studies conducted previous to our study attempting to calculate the amount of tooth structure loss for different preparations and materials in teeth of different morphologies.
The first study chronologically performed by Edelhoff et al (24, 25) consist of two separate articles; one study for posterior teeth and one for anterior teeth. In this study, the preparations are mainly for partial coverage restorations and the amount of tooth structure loss has been calculated for the coronal aspect of the tooth. What is more, the preparation guidelines that were used for the full coverage restorations for the study are more aggressive than the guideline used for our study. The more aggressive tooth structure removal of Edelhoff study can possibly be due to the inferior properties of the materials in the time the study was conducted (the study was conducted in 2002).

The second similar study was conducted by Al-Fouzan et al (26).

In this study, micro CT-scan was used for measuring the amount of tooth loss after preparation. Similar to Edelhoff’s study, partial coverage restorations were also included in the investigation. The formula used in this study for calculating the volume of structure loss was as follows:

\[
\text{volume of the reduced tooth structure} = \text{volume of the crown before preparation} - \text{volume of the crown after preparation}.
\]

As discussed earlier in this chapter, as the initial weight of samples is not considered in this equation, this can bring inaccuracy to the calculation. What is more, the value for axial reduction for “all ceramic crown” is different than our study. As this study calculated the amount of volume loss in the whole tooth, the results were similar to our study from this stand point however, the study only reported the mean differences of the groups and not the actual mean for tooth structure loss of each group.

The third and last similar study is the research by Clark et al (27). In this study, the authors prepared acrylic resin teeth for zirconia and full metal crowns based on different manufacturers’ guidelines for two tooth morphologies of maxillary right central incisor and mandibular right first molars. The manufacturer’s guidelines in this study mainly provided range of values for reductions. Only one guideline for zirconia preparation in this research provided exact reduction values rather than range of values, but the given values are different than the ones used in our study. To add to this, the variable utilized for this study was the net weight loss. As discussed in
multiple parts of this chapter, this might bring minor inaccuracies to the analyses as this equation
does not involve the initial weight of samples.

For different reasons mentioned in detail above, the results of the previous studies are not
comparable with our study.

It should be noted that the mechanical properties of dental materials are constantly enhancing.
The consequent more conservative recommendations and preparation guidelines will make
future similar comparisons different. In our study, the amount of axial reduction for a full
coverage zirconia preparation was 0.8 mm and for lithium disilicate glass-ceramic was 1 mm.
Some guidelines today are endorsing axial reduction of as low as 0.5 mm for zirconia and as low
as 0.8 mm for lithium disilicate glass-ceramic full coverage preparations. Changing the values
accordingly can significantly affect the results of the study.

Limitations of the Study and Recommendations for Future Research

With advancements in the field of digital dentistry, future study methodologies could be modified
to provide a more precise, accurate answer to our research question.

Utilizing a 3-dimensional scanner or a micro CT-scan with software that calculates the volume
loss of only the coronal aspect of the tooth could potentially be a more effective approach than
this study’s methodology. Using these technologies could provide results that measure the
amount of coronal tooth structure loss as a more comprehensible value for clinicians rather than
the amount of tooth loss from the whole tooth. Also, with these technologies, the software
measures the volume change irrelevant of the weight of tooth, so the necessity to consider
weight difference of natural tooth tissues is eliminated. Therefore, the study could be conducted
with extracted human teeth that would be a better simulation of a clinical setting.

Despite increasing the sample size of our study from what was initially calculated with the given
confidence intervals and margin of error, a study with a larger sample size may have more power
that can potentially result in more meaningful comparisons showing smaller differences.
Chapter 6 : Conclusions

Within the limitations of this study, zirconia full coverage preparations preserve statistically significant more tooth structure compared to PFM and lithium disilicate glass-ceramic full coverage crown preparations.

Our results did not exhibit a statistically significant difference between the amount of tooth structure loss for full coverage restorations of PFM and lithium disilicate glass-ceramic for three different tooth morphologies of maxillary left central incisor, left first premolar and left first molar.

First maxillary premolars had the highest mean percentage of tooth structure loss when prepared for different full coverage crowns.

Metal occlusal PFM full coverage preparation for maxillary molar statistically preserves the same amount of tooth structure as lithium disilicate glass-ceramic and conventional PFM full coverage preparations do for the same tooth morphology.
References:


