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ABSOLUTE MARGINAL DISCREPANCY OF PROCERA® ALLCERAM INCISOR AND MOLAR CROWN COPINGS.

DISSERTATION WORK IN DENTISTRY

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INTRODUCTION

1. INTRODUCTION

The most common dental treatment that the patients seek in prosthetic dentistry is crown or fixed partial denture. Recent material, technical and clinical innovations in ceramic materials have increased the complexity of material selection and treatment planning. Metalo-ceramic restorations represent the most popular and successful treatment modality. Long-term clinical studies have proved that metalo-ceramic restorations are durable and long lasting [96, 97]. Although, metalo-ceramic restorations had some limitation of satisfying the optical properties of the natural teeth, and few patients reported an allergic reaction, hypersensitivity to the base metal alloys used in ceramo-metal crowns [77], recent research work on material technology and manufacturing of ceramics have provided more aesthetic, biocompatible, and high strength all-ceramic restorations. The modern and novel method of CAD/CAM based restoration production provided the more realistic alternative to metalo-ceramic restorations.

The quest for all-ceramic materials with properties that would enable their use in stress bearing area has led to the development of many new materials and processing techniques. In 1965, McLean *et al.* [52] suggested the usage of aluminum oxide to strengthen feldspathic ceramic, which marked the beginning of use of oxide based ceramic. The strongest and toughest oxide ceramics used today are based on aluminum oxide (alumina), and the recent material being zirconium dioxide [17]. Andersson and Oden introduced CAD/CAM based aluminum oxide restoration Procera® AllCeram crowns and bridges in 1993 [Procera, Nobel Biocare, Sweden] [3] by using 99.5 % purity aluminum oxide.

The three primary criteria for selection of restorative materials for crown and bridge restorations are marginal fit, strength and aesthetics. This also decides the clinical longevity of the all-ceramic materials [44]. Today, dentists can choose from a variety of all-ceramic materials as sub-structure for crown and bridge restorations to satisfy the aesthetic and functional demand of the patient. Success rate of the recent materials in anterior and posterior teeth are promising. CAD/CAM produced aluminum oxide restoration Procera® AllCeram crowns and bridges are being used since 12 years. Recently published long-term results are promising [106].

The marginal gap of restoration is very critical for the long-term survival of the full coverage restorations [57]. If the restoration has wider gap at the margin area then the luting agents are exposed to the oral fluids and dissolution of luting cement ensues. This sets in microleakage and ingress of oral fluid and bacteria [29, 86]. These can cause the caries, gingivitis and periodontitis. Marginal gap evaluation of restorations depends on multiple factors [10]. Clinically accepted marginal gap of CAD/CAM restoration has been suggested to be 100 µm to 120 µm [53]. The positive factors affecting the marginal adaptation of Procera® AllCeram crowns need to be studied *in vitro* for the better understanding.

2
LITERATURE REVIEW

2.1 EVOLUTION OF PORCELAIN

Early History

Glasses are thought to be the first material produced by man accidentally when a wood fire was made on a bed of silica sand. Historically, three basic types of ceramic materials were developed: Earthenware, Stoneware & Whiteware. Ceramics are also considered to be the earliest group of inorganic materials to be structurally modified by man. The first ceramics fabricated by man were earthenware pots used for domestic purposes. The earliest burnt clay objects used by the potters were reported from Czechoslovakia approximately in 23,000 BC [93].

Chinese Porcelain

Stoneware had been produced in China by 100 B.C., and by the 10^{th} century A.D., ceramic technology in China had advanced to a highly sophisticated stage [100, 44]. In 1375, porcelain was copied in Florence, and rapidly became popular throughout Europe. As the trade with the Far East grew during the 17^{th} century, this superior material came to Europe from China. However, the trade with the Far East could not satisfy the high demand for porcelain in Europe. So strenuous efforts were made by the European pottery industry to imitate the Chinese porcelain, but it was found impossible to reproduce the translucency of Chinese porcelain

This situation prevailed for some time until in 1717, Father d'Entrecolles leaked the secret of Chinese porcelain, from China. He managed to acquire samples of the materials used, together with a detailed account of how the porcelain was manufactured and sent them to a French friend of his, who passed it onto M. de Reamer a scientist who was able to identify the components used by the Chinese as kaolin, silica and feldspar. It was not long before the dental potential of this material was recognized.

From this early work, stemmed all the developments in ceramic technology and the remarkable fact was that the early ceramists were exploiting almost all the properties of solids that are the concern of the modern solid state physicists. With the exception of electrical and magnetic effects, the ceramists were sometimes inadvertently using properties such as moisture derived from vitrification and devitrification, the nucleation of various crystalline phases and local variations of viscosity, surface tension and expansivity. Colours depended on various states of oxidation, abnormal ionic states and on structural imperfections in the crystals. The dental application of porcelain material finally came about in the 18th century in Europe.

History of porcelain use in dentistry

The history of the use of porcelain as a dental material dates back nearly 200 years [6,15, 16, 19, 80, 82 100,]. Pierre Fauchard first mentioned the use of porcelain in dentistry. Fusing ceramic material to gold or silver used to have superior surface and colouring quality. This involved the use of low fusing glazes, which had been known for some hundreds of years and had reached artistic eminence in the work of Cellini

1728 – Pierre Fauchard, a French dentist first proposed the use of porcelain in dentistry. He suggested the use of jeweller's enamel to fabricate artificial teeth.

1774 – Alexis Duchateau, a French apothecary with the assistance of a Parisian dentist Nicholas Dubois de Chemant, made the first recorded successful porcelain dentures at the Gerhard Porcelain Factory, replacing the stained and malodorous ivory prostheses of Duchateau. This was the first use of porcelain in its true form [a fused composition of the minerals Kaolin, Quartz and Feldspar], to form denture teeth.

1788 - Nicholas Dubois de Chemant continually improved porcelain formulations and first displayed a baked porcelain denture made in a single block.

1806 to1808 – Giuseppangelo Fonzi an Italian dentist who worked in Paris introduced the first individually formed (single) porcelain teeth that contained embedded platinum--pins. But they never met with great approval because of their brittleness and opacity. He also used metallic oxides to produce 26 shades of colour in porcelain.

By 1825- Samuel Stockton began fabrication of fused porcelain teeth in Philadelphia. His initials were represented in the name of the S.S.White Company.

1850 – Samuel Stockton of Philadelphia, his nephew S. S. White and Claudia Ash, in England placed the porcelain tooth on a successful commercial basis.

1880 - Porcelain was first applied to restorative dentistry (development of the Richmond and Logon & Davis crowns).

1884 – Charles H. Land pioneered the development of the first glass furnace for fusing porcelain.

1887 – C.H. Land of Detroit developed the first All-Porcelain jacket crown [PJC] using the Platinum Foil Matrix technique.

1962 - M. Weinstein, S. Katz & A. B. Weinstein was awarded the U.S patent for gold alloy formulation and feldspathic porcelain designed for porcelain fused to metal restoration.

1963 to 1965 – Mc Lean & Hughes in England developed the first viable technique for Alumina-reinforced crowns.

1983 - First dental CAD/CAM prototype was presented at the Garanciere Conference (in France).

1985 – First CAD/CAM crown was publicly milled and installed in the mouth.

2.2. Composition of ceramics

Ceramics is a term generally applied to all useful or ornamental objects that are baked. The term 'Ceramics' is derived from the Greek word **'Keramos'** meaning, "burnt stuff", 'keramikos' means 'earthen' [100, 44]. Ceramic art comprises of all art objects made of baked clay such as vases, urns, cups, statuettes etc, and includes all varieties of artistic earthenware and porcelain. True Porcelain, which appears translucent, vitreous and basically white, is a kind of pottery formed from a specific type of clay, quartz or quartz substitutes.

Ceramics are compounds of metallic and non-metallic elements such as oxides, nitrides and silicates. 'A Ceramic, is therefore an earthy material usually of a silicate nature and may be defined as: A combination of one or more metals, with a non-metallic element, and usually oxygen

Ceramics from the finest 'porcelains or china' earthenware are composed of essentially the same materials, the principle difference being in the proportion of the primary ingredients (such as feldspar, silica and kaolin/ clay) and firing procedures (temperature, method etc). Other compounds such as potash, soda or lime are often added to give special properties.

Porcelain in English and many other foreign languages refers to 'china'. Actually the word **'Porcelain'** originates from the French word **'porcelaine'** or the Italian word **'porcellano'**. Those kinds of pottery or ceramic ware which have a translucent or semi-translucent body with superior whiteness or hardness and which are fusible at very high temperatures are generally spoken of as porcelain or china/chinaware. Ceramic materials containing additional important ingredients [clay, feldspar, silica] were given the name "Porcelain"[82].

2.3. Dental Porcelain

Fused porcelain could be produced in almost every shade or tint and its translucency imparted a depth of colour unobtainable by other materials. In addition to favourable aesthetic properties and excellent biocompatibility, the development of translucency and improvement in strength made this form of porcelain suitable for dental applications. The precise formulations of dental porcelains vary among the available products. However, the general trend towards using less of kaolin (clay with an increase in the feldspar content) in order to improve its translucency suggests that dental porcelains should be considered as "Feldspathic glasses with crystalline inclusions of silica".

In dentistry, three different types of porcelain compositions are used

Denture tooth porcelain	**Feldspathic porcelain**	**Aluminous porcelain**
Mixture of powders of feldspar, clay and quartz. [High fusing porcelain]	Ceramo-metal restorations, powders of potassium feldspar and glass. Used for veneers and inlays.	Porcelain jacket crown, Similar to that of feldspathic porcelain with increased amounts of aluminium oxide

Composition

The various ingredients used in different formulations of ceramics [80, 82] are:

1. **Silica (Quartz or Flint)** – Filler
2. **Kaolin (China clay)** – Binder
3. **Feldspar** – Basic glass former
4. **Nepheline, Syenite & Leucite**
5. **Water** – Important glass modifier
6. **Fluxes** – Glass modifiers
7. **Colour pigments**
8. **Opacifying agents**
9. **Stains and colour modifiers**
10. **Fluorescent agents**
11. **Glazes and Add-on porcelain**
12. **Alumina**
13. **Alternative Additives**

2.4. All-ceramic systems

Porcelain is the most natural appearing synthetic replacement material for missing tooth substance, available in an extensive range of shades and translucencies for achieving life-like results. The unique advantage of porcelain is due to light absorbing and light scattering behaviour of the material and its potential to reproduce the depth of translucence, the colour, and the texture of natural teeth. However, its aesthetic appearance was compromised when it was fused to a metal substrate in an effort to strengthen porcelain. These drawbacks together with the material and labour costs associated with metal substrate fabrication have prompted the development of new all ceramic system that do not require metal, yet have the high strength and precision fit of ceramo-metal systems.

Furthermore, there is no known risk of developing adverse reactions to the porcelains, as it has been documented for metal alloys [75]. There are, however, drawbacks to the use of dental porcelains. Despite high bonding forces between the atoms, the material cannot withstand deformations of more than 0.1 % without fracturing [44, 54]. This brittleness is due to the nature of the strong covalent bonds that do not allow plastic deformation when subjected to tensile or shear forces.

The term **"All-Ceramic"** refers to – Any restorative material composed exclusively of ceramic, such as feldspathic porcelain, glass-ceramic, alumina core systems and certain combination of these materials [26]

All-ceramic restorations advantages over Metalo-ceramic system:

- Increased translucency [37, 38]
- Improved fluorescence [75]
- Greater contribution of colour from the underlying tooth structure
- Inertness
- Biocompatibility [78]
- Resistance to corrosion

- Low temperature / electrical conductivity

2.5. Classification of all-ceramic materials

A. Classification according to the method of fabrication [82]:

1. Conventional Powder & Slurry Ceramics: Using condensing & sintering.

a) Alumina reinforced Porcelain e.g.: Hi-Ceram
b) Magnesia reinforced Porcelain e.g.: Magnesia cores
c) Leucite reinforced (High strength porcelain) e.g.: Optec HSP
d) Zirconia whisker – fibre reinforce, e.g.: Mirage II (Myron Int)
e) Low fusing ceramics: (a) Hydrothermal LFC e.g.: Duceram LFC
(b) Finesse (Ceramco Inc)

2.Castable Ceramics: Using casting & ceramming

a) Flouromicas e.g.: Dicor
b) Apatite based Glass-Ceramics e.g.: Cera Pearl
c) Other Glass-Ceramics e.g.: Lithia based, Calcium phosphate based

3. Machinable Ceramics: Milling machining by mechanical digital control

A. ***Analogous Systems [Pantograph systems – copying methods]***

a) Mechanical e.g.: Celay
b) Automatic e.g.: Ceramatic II, DCP
c) Erosive techniques: a) Sono-erosion e.g: DFE, Erosonic
b) Spark-erosion e.g: DFE, Procera

B. Digital systems (CAD / CAM)

a) Direct e.g: Cerec 1, Cerec 2 and 3.
b) Indirect e.g: Cicero, Denti CAD, Automill, and DCS-President

4) Pressable Ceramics: By pressure molding & sintering

1) Shrink-Free Alumina Reinforced Ceramic (Injection Molded)

E.g.: Cerestore / Alceram

2) Leucite Reinforced Ceramic (Heat – Transfer Molded)

E.g.: IPS Empress, IPS Empress 2, and Optec OPC.

5. Infiltrated Ceramics: by slip-casting, sintering & glass infiltration

1) Alumina based e.g.: In-Ceram Alumina

2) Spinel based e.g.: In-Ceram Spinel

3) Zirconia based e.g.: In-Ceram Zirconia

B. Recent classification according to Kelly [45]**:**

a. Predominantly glassy materials,

b. Particle filled glasses,

c. Polycrystalline ceramics.

Table: 2.1 and 2.2 gives some commercial examples and composition of different ceramic systems,[45]

Table 2.1 Aesthetic ceramics: composition, uses, and commercial examples

Base	**Fillers**	**Uses**	**Commercial examples**
Predominantly glassy ceramics			
Feldspathic glass	Colorants Pacifiers High-melting glass particles	Veneer for ceramic substructures, inlays, inlays, veneers	Alpha, VM7 (Vita) Mark I I (Vita) Allceram (Degudent)
Moderately filled glass ceramics			
Feldspathic glass	Leucite (**17-25** mass %) Colorants Opacifiers High-melting glass	Veneer for metal substructures, inlays, veneers	VMK-95 (Vita) Omega 900 (Vita) Vita Response (Vita) Ceramco1 1

	particles		(Dentsply) Ceramco 3 (Dentsply) IPS d.SIGN (Ivoclar-Vivadent) Avante (Pentron) Reflex (Wieland dental)
Highly filled ceramics			
Feldspathic glass	Leucite **(40-55** mass%) Colorants Opacifiers	Single- unit crowns, inlays, inlays, veneers	Empress (Ivoclar) OPC (Pentron) Finesse All-Ceramic (Dentsply)

Table 2.2 *Substructure ceramics: basic composition, uses, and commercial examples*

Glass	**Fillers**	**Uses**	**Commercial examples**
Highly filled glassy ceramics			
Feldspathic glass	Leucite **(40-55** mass%)	Inlays, Onlays, Veneers, Single-unit crowns	Empress (Ivoclar) OPC (Pentron) Finesse All-ceramic (Dentsply)
Feldspathic glass	Aluminum oxide **(55 mass%)**	Single- unit crowns	Vitadur-N (Vita)
Lanthanum	Aluminum oxide **(70% vol %)** Zirconium oxide (20vol%)	Single-unit crowns, Anterior three-unit bridges	In-ceram Zirconia (Vita)

Modified feldspathic glass	Lithium disilicate **(70 vol%)**	Single-unit crowns, anterior three-unit bridges	Empress2 (Ivoclar) 3G (Pentron)
Polycrystalline ceramics			
Aluminium oxide	More than 0.5 mass%	Single-unit crowns	Procera (Noble Biocare)
Zirconium oxide	Yittrium oxide (3–5 mass %)	Single-unit crowns	Procera (Noble Biocare)
Zirconium oxide	Yttrium oxide (3-5 mass %)	Single-unit crowns, Three-unit bridges, Four-unit bridges	Cercon (Dentsply) Lava (3M-ESPE) Y- (Vita)

2.6. Compatibility of Ceramic – Ceramic Systems

All Ceramic systems that provide increasingly higher strength and esthetic potential for replacing natural teeth continue to be developed [85]. Many of these systems are unusual in that they have high Coefficient of Thermal Expansion (CTE), often more than twice that of conventional all-ceramic materials.

Crystalline leucite is the strengthening phase in these systems and is the same mineral giving metal ceramic porcelain their high expansion properties [45]. Leucite is often chosen as strengthening filler, because its refractive index matches with feldspathic porcelains, and minimizes the opacifications seen with other fillers (e.g.: alumina). Esthetic porcelains now available; range in leucite content from 0-51 % by wt, traditional metal-ceramic systems contains approximately 12 to 40 wt %. When such complete ranges of all-ceramic materials are available, the possibility of cross-system compatibility (i.e., between manufacturers) is raised. E.g.: Dicor coping (Dentsply/ York Div, York Pa) low-expansion glass-ceramic can be veneered with a compatible low expansion alumina reinforced core Vitadur-N (Vita Zahnfabrik, Bad Sackingen, and Germany) [31].

If the Coefficient of thermal expansion **[CTE]** of porcelain [CTE_p] is much lower than that of the metal **[CTE_M]**, tangential cracks will form upon cooling as a result of tensile stresses oriented perpendicular to the external surface. Similarly, if the CTE_p is higher than that of metal, cracking will occur in a radial fashion upon cooling. The stresses that cause such cracking are directly proportional to the difference in CTE between the two materials, as well as the magnitude of the temperature during cooling. Therefore, successful all-ceramic material combinations should have well matched CTE's [difference of not more than $1 \times 10^{-6}/°C$] to avoid the incompatibility stresses that lead to cracking [35, 44, 45].

Main causes for clinical failure of all-ceramic restoration are: cracks originating from flaws on internal surface and voids within the ceramic and the layer of luting material directly below the occlusal section and areas of stress concentration. Modern feldspathic ceramic systems are reinforced using alumina, leucite or glass-fibers to make them more resistant against crack development and propagation. Recent long-term clinical study results are very promising [56, 63, 76].

2.7. Comparison of the properties of all-ceramic system

Product Name	Flexural Strength	AbrasivenessVs.Natural Tooth (Hardness)	Special Equipment Needed	Other Characteristics
Conventional Powder – slurry				
Optec HSP (Jeneric/ Pentron)	146Mpa	Higher than that of conventional feldspathic porcelain due to high leucite content.	Special die material	No core material; uniform translucency and shade throughout; etchable for bonding to tooth
Duceram LFC (Degussa)	110Mpa	Close to hardness of natural tooth owing to absence of leucite	Special die material	Low-fusing temperature; can be characterized with surface stains.
Castable Ceramics				
Dicor (Dentsply, L.D. Caulk Division)	152Mpa	Same as that of tooth (softer than conventional feldspathic porcelain); however, Dicor Plus is as hard as conventional feldspathic porcelain	Special investment and casting equipment	Surface stains (aesthetics) can be lost to abrasion and acidulated fluoride (Dicor Plus is more stable); etchable core for bonding to tooth
Machinable Ceramics				
Cerec Vitablocs Mark I (Vidnet)	93Mpa	Similar to that of conventional feldspathic porcelain	Siemens Cerec CAD-CAM system; milling of a ceramic ingot from a digitized optical-scan.	Regardingall materials in this group : - Can be characterized with surface stains; the stains may be lost to abrasion

Cerec Vitablocs Mark II (Vident)	152Mpa	Similar to that of enamel Between those of Cerec Vitablocs Mark I and Cerec Vitablocs Mark II	Same as above	- The marginal gap is wider than that in other all-ceramic system; wear of the resin cement in this gap may have clinical significance. - Etchable for bonding to tooth structure
Dicor MGC (Dentsply, L.D.,Caulk	216 Mpa	Same as that of Cerec Vitablocks Mark II	Same as above	
Celay (Vident)	Same as Cerec Vitablocs Mark II		Celay copy milling system. -milling of a ceramic ingot from a direct pattern	
Pressable ceramics				
IPS Empress (Ivoclar N. America)	126 Mpa initially; 160-182 Mpa after heat treatment	Possibly higher than that of conventional feldspathic porcelain due to increased leucite content after heat treatment	Special oven, die material and molding procedure	Core material is shaded and translucent; etchable for bonding to tooth
Optec OPC (Jeneric /	165 Mpa	Same as above	Same as above	Same as above

Pentron)				
Infiltrated Ceramics				
In-Ceram (Vident)	450Mpa	Same as that of conventional feldspathic porcelain	Special die material, high-temperature oven	Core material is more opaque than other types; Not etchable for bonding to tooth

Table: 2.3. *Comparison of the all-ceramic restorative systems [20, 35, 41, 84, 85].*

2.8. Machinable ceramics

Regardless of the advanced state of the 300-year old technique of casting, each of its steps could induce error in the final casting. Until 1988, indirect ceramic dental restorations were fabricated by conventional methods (sintering, casting and pressing) and neither was pore-free. Machining blocks of pore-free industrial quality ceramic can produce pore-free restorations [49, 51]. The tremendous advances in computers and robotics could also be applied to revolutionize dentistry and provide both precision and reduce time consumption. With the combination of optoelectronics, computer techniques and sinter-technology, the morphologic shape of crowns can be sculpted in an automated way [88]. Registration of the mandibular jaw movements or of the functionally generated path in the mouth provides the necessary data for an interference-free escape of cusps from their fossae.

CAD/CAM is an acronym for Computer Aided Design/ Computer Aided Manufacturing (or Milling).

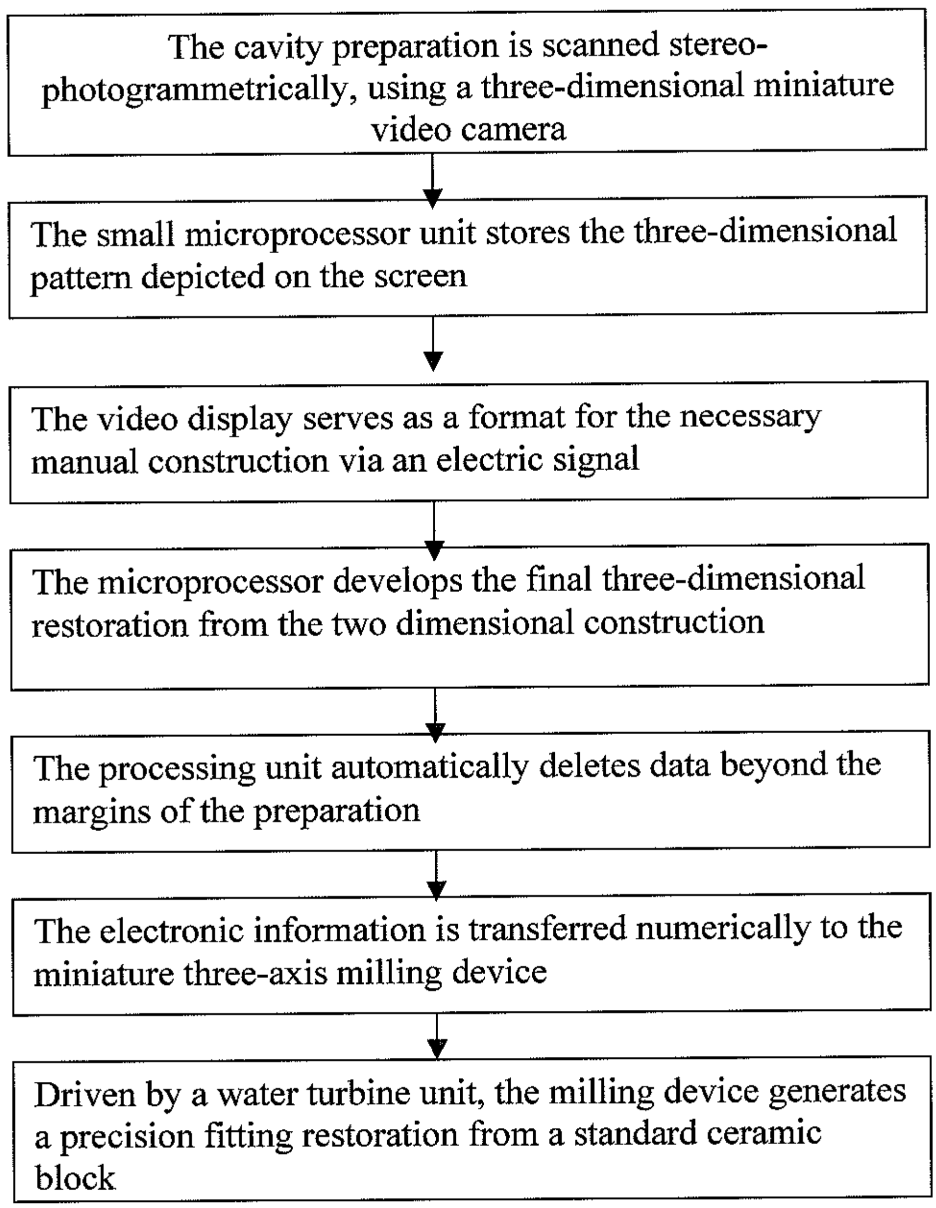
Triad of fabrication: Fabrication of a restoration whether with traditional lost-wax casting technique or a highly sophisticated technology such as a CAD/ CAM system has three functional components [76]:

Data acquisition or information is captured electronically, either by a specialized camera, laser system, or a miniature contact digitiser.

Restoration design is done by the computer – either with interactive help from the user or automatically.

Restoration fabrication includes machining with computer controlled milling machines, electrical discharge machining and sintering

2.4. Flow chart demonstrating the sequential events occurring during CAD/CAM technique of fabrication of the ceramic restoration.



The entire process of electronic designing and subsequent milling of a ceramic restoration depends on the individual system of fabrication.

2.9. Procera® CAD/CAM production of dental restorations

The restorative dentistry has created a real industrial and technological revolution in the 20th century. This has provided dental profession numerous opportunities to select materials and technique to satisfy the clinical demand. However, the search for a better non-metallic restorative material that has same mechanical strength, biocompatibility like metal, but with better aesthetics and marginal adaptation has continued. In this direction a great amount of scientific research and structural modification of ceramic materials has been done to satisfy the golden requirement of the oral environment.

The introduction of the alumina into dentistry was marked as the starting of high strength oxide based ceramic with high fracture resistance. Furthermore, industrial production of dental restorations using computer-aided designing/computer-aided manufacturing CAD/CAM made the production more accurate, effective and with less human errors. In 1993 the PROCERA® CAD/CAM system was developed by **Matts Anderson and Oden A** by a co-operative effort between Nobel Biocare AB, Goteborg and Sandvik Hard materials AB in Sweden [3].

The Procera® system is based on the CAD/CAM technology for production of all-ceramic crowns and bridges from alumina, zirconium or titanium based metal-fused-ceramic restorations for tooth supported and implant supported restorations. In this system, CAD [Computer-Aided Designing] uses the "contact scanner" to digitise the intricate details of the tooth die preparation. Using the computer, this information can be converted into 3-dimensional dot clouds. This data can be processed further using the user-friendly software to redefine the cervical margins, and design the framework of proposed restorations with uniform thickness, uniform cement space and other details. This information can be "transmitted" via modem to the distant production facility [Procera® Sandvik AB Stokholm].

In Procera system during production of restoration, without the die being in physical form, the computer program plans the shape and profile of the substructure of restoration

3-dimensionally. Final restorations will be fabricated using CAM system using densely sintered high-purity aluminium-oxide [99.5 % of Al_2O_3] or All Zirkon [Zirconium] or AllTitan [Titanium] framework [24]. This framework undergoes rigid quality control and will be mailed back for clinical inspection. Finally, ceramist will veneer with aesthetic ceramic to match the shade, form, and size of the natural teeth. This system has undergone vigorous clinical trial and modification following it's inception and is popular among other CAD/CAM systems.

2.9.1 Stages of scanning

In the Procera® system, [Nobel Biocare AB, Gothenburg, Sweden] the chain of geometrical data transferring starts with surface digitisation of the tooth die preparation. It utilizes touch-probe scanning [3, 4] for digitisation of the models. Commercially available touch-probe scanner [M50; Nobel Biocare AB] has 2.5 mm in diameter sapphire ball. This contacts the die surfaces when it is rotating during scanning procedure [66, 67]. The digitisers will be calibrated before the scanning starts according to the manufacturer's recommendations.

The tooth preparation die is trimmed below the finish line using the large pear-shaped bur, to achieve a better definition of the marginal line. The refined die is placed on the scanner base in vertical position. A laser light helps to orient the die's vertical axis of rotation to the instruments. The contact probe is positioned below the finish line of the die with constant pressure of 17 grams at 45-degree angle to the axis of rotation of the die. The scanning process starts by rotation of the contact-probe, 360 degrees around the die. The scanner collects single data point at every degree of rotation during scanning. After completing every turn, the contact-probe elevates continuously by 200 μm till the entire surface of the die is registered. The whole scanning generates an average of 25000 to 50000 dots in 3 minutes. This scanning generates digitised "point cloud" of complete details of the tooth preparation die on the computer screen [25, 66, 67]. The point clouds are further processed with the help of user-friendly software provided with system [Procera System C3D, version 1.4; Nobel Biocare AB].

During the scanning, using integrated software application of the scanner, 3-D model will be calculated from the offset of the point cloud, based on the radius of the sapphire ball. Combining the points to a 3-D polygonal model will automatically create a 3-D surface model [66, 67] called as CAD reference model **[CRM]**. The colour difference maps the distribution of surface discrepancy [undercut areas in red]. To avoid the interference of points below the margins, manual removal of these points will be performed from the clouds that are to be used as the CRM.

The dot points in the point clouds are denser and more in number in anterior than molar models, due to larger radius of the molar die compared to anterior die. During rotation of the scanning table, helical motion of the probe can be influenced by its angle of approach toward the surface of the die. And the diameter of the probe also influences the registration of the concave and convex surface variation of the tooth preparation, e.g. rounded slope of the chamfer. This was proved in earlier study of internal fit that, wide gap at the deepest portion of the chamfer finish line and junction of axial and occlusal surface [46, 58]. But sharp surface [edge of chamfer] reproduction has a negative effect over the accuracy of the fit [65].

Accuracy of the Procera contact scanners were evaluated by Persson *et. al.*, and found the accuracy is as close to 10 µm [66]. But study of internal fit and marginal fit [58] demonstrated accuracy of scanner as 14 µm. We have to note that difference in methodology used to evaluate the same. Research suggested [18] to improve the accuracy of 3D computer models by removing the rotation errors during scanning and also suggested the consideration of the factor like setting expansion of the dental die stone.

2.9.2. Alternative methods of the 3D data

Among the various methods of digitising the geometrical body of tooth preparation and form, optical method based on either laser or white light are very popular. In laser scanner or white light, white light with high intensity is projected onto an object, and reflected patterns are registered by digital camera. In CEREC III system, digitisation device works on the principle of **"active triangulation"** [55]. During the scanning the reflections of the die preparation will be traced using camera image, finally, 3D point cloud of the tooth preparation will be obtained using triangulation technology.

The scanner consists of a table with a model holder and a laser. This also has high-resolution digital camera to capture the image of line as it is projected on to the object. The model to be digitised is fixed on the holder. To ensure complete coverage of the geometry of the object, the table can be rotated and tilted in horizontal axis. To allow the scanning to be more accurate different colour of die stone can also be used.

The scanned image can be processed with the software provided by the manufacturer. The surface creation of software automatically optimises the data and reduces the number of point cloud. Then by combining the point to a 3-D polygonal model, a 3-D surface of a model can be automatically created [12]. Laser scanners are very advantageous for scanning soft and brittle material. The optical properties of the object can also affect the accuracy of the scanned data [66]. The accuracy of the laser scanner appears to be as accurate as contact scanner [66, 67, 18].

2.9.3. CAM requirement and production

Final designed restoration digital data are processed at the Computer Aided Manufacturing [CAM] centers, which are either located at the laboratory or at a distant place in any geographical location for production of dental restoration. Most systems can produce single crowns or large bridges of 3 to 4 units. According to the technique used for industrial production, CAM technologies can be divided into three groups:

A. Subtractive technique from a solid block:

This technique is the most commonly used method. The contour of the framework is milled from an industrially prefabricated, solid material block using burs, diamonds or diamond disk. The material block can be in the green stage, partially sintered, or may require further processing [sintering, glass infiltration]. The precise fit of the restoration depends on the size of the smallest tool used during milling procedure. Manual precision seating is still required for all materials used [4, 102].

B. Additive technique by applying material on a die:

In this technique, the powder material is applied directly on the die of the master model. With the Procera system (Nobel Biocare, Goteborg, Sweden), powder material is applied on an enlarged metal die and compacted under pressure. The framework, which is in green stage, is removed from the die and sintered to correct size [1550°C]. A CAM process creates the outside contour of the coping, while the powder is on the metal die in the green stage [4, 102].

C. Solid free form fabrication:

In this method, the selective laser sintering technique allows the build up of ZrO_2-frameworks in a powder bed. Heat-fusible powder materials are applied layer by layer, on the spots that are indicated from the CAM-model. And then they are selectively sintered by a laser to form the final framework. With this system, the frameworks can be designed in the dental laboratory (CAD) and fabricated in a producing center [Bego Manufacturing-System, Bego Medical, Bremen, Germany] [102].

2.9.4. Studies on the survival rate of the metalo-ceramic restorations

There are multiple factors related to the long-term success of any full coverage restoration. According to consensus among the researchers, it has been concluded that the prosthetic restorative system can be considered successful if it demonstrates a survival rate of 95 % after 5 years and 85 % after 10 years [96, 97]. Success of a dental restoration is the main concern for clinician and manufacturer but this equally important for patients.

Long term study evaluating the successes rate of metalo–ceramic restoration showed a success rate of 96 % for 5 years, 87 % for 10 years, and for 10 years it was 85 %. Reported modes of failure of the metalo-ceramic restorations were tooth fracture [38%], periodontal breakdown [27 %], loss of retention [13 %] and caries [11 %]. An earlier study by the same authors reported that the primary cause of failure was due to dental caries [38 %]. Critical observation of the data reveals that biologic factors which affected the success rate amounts up to **40 %** of the total failure rate.

In long-term clinical study, consisting of 102 patients who received 108 FPDs made of cast gold and heat cured acrylic veneering. The senior students of the Dental faculty at the University of Oslo made the restorations. The reported survival rate was 96 %, 88 % and 68 % after observation periods of 5, 10 and 15 years, respectively [95].

2.9.5. Factors that influence the success of All-ceramic crowns

There are many factors contributing to the success of All-ceramic crowns. They can be first related to operator and secondly related to the patient.

Patients related factors could be

- High-risk caries group with low local fluoride intake
- High sugar intake, low salivary rate [geriatric patients]
- Risk of periodontitis [poor oral hygiene, smoking, genetic factors]
- Patient's involvement with high trauma risk sports.
- When clinical crown length is less than 3 to 4 mm.
- Bruxism

Operators' related factors:

- Inefficient clinician with no sound clinical judgement in case selection
- Lack of systematic approach to patient
- Inappropriate tooth preparation.
- Faulty impression technique
- Placement of the crown in wet conditions.
- Ineffective motivation of patient recall.

2.9.6. Principles of tooth preparation for all-ceramic crowns

Tooth preparation is one of the most important stages of starting the rehabilitation of the lost portion of the teeth or teeth. This has to be done with extreme care and precision. The biomechanics of the tooth preparation should satisfy biological and mechanical factors and provide good support for the displacement forces. Final guide to tooth preparations will be guided by the clinical situation. It will be appropriate to follow manufacturer's recommendation for tooth preparation.

The recommended preparation design for all ceramic restorations requires a total occlusal convergence angle between 4 and 6 degrees [21, 22], an occlusal reduction of 2 mm, an axial reduction of 1.0-1.5 mm and a minimal occluso-cervical dimension of 4mm. Shoulder or chamfer finish lines can be used with depths between 0.8 and 1.2 mm, depending on the ceramic restorative material and the cementation procedure. All line angles should be rounded and the tooth preparation should be smooth [30].

The fabrication of CAD/CAM restorations demands a preparation design of high quality, with distinct preparation finish lines, undercuts and sharp angles should be avoided. Depending on the specific CAD/CAM system used, the preparation requirements vary. Most systems recommend a shoulder or deep chamfer preparation [LAVA, CICERO, Cercon smart ceramics].

Variations can be also found between different systems for the amount of axial tooth removal. For example, the minimum thickness for a Lava-framework is 0.5 mm, whereas Cercon smart ceramics suggest a reduction of 1mm and CICERO 0.7-1.2 mm [51]. The preparation demands for the Procera system and the Cerec-system are similar to those for a metalo-ceramic restoration [51].

2.9.7. Marginal integrity of AllCeramic restorations

The all-ceramic restorations should comply with three critical demands to be successful in the clinical situations. They include strength of a material, aesthetics and marginal fit [44]. The aesthetics is very important for the patients, but the other two factors like strength and marginal fit are very important for the dentists. Any prosthodontic restorations can survive in oral biological environment only if the margins of the restorations are closely adapted on to the cavosurface finish line of the preparation. The configuration of the finish line preparations dictates the shape and bulk of the restorative material at the margin of the restoration. It can also affect both marginal adaptation and the degree of seating of the restorations.

The principle of the marginal adaptation marginally differs in CAD/CAM restoration because of differences exists in the production technique. Direct comparison of marginal fit values of the CAD/CAM restorations to metal fused ceramic restorations cannot be done due to many factors such as, elimination of the human errors during production, digitalisation of tooth model, and different amount of cement spacing incorporation. The recommended margin configuration for Procera® AllCeramic system was shoulder with rounded internal angle and deep chamfer of 0.8 to 1.2 mm wide. But earlier study did not find any relationship between margin design and marginal fit of AllCeram crown [72].

The method of digitisation of prepared tooth also has some influence on the marginal fit and internal fit of the CAD/CAM crowns. The accuracy of the Procera® scanner [M50; Nobel Biocare AB] was found to be ±10μm [66]. Studies regarding the marginal fit and internal fit found that deepest portion of the chamfer preparation had more wide space compared to the other spaces in the internal area [58, 46]. All the studies found that the marginal fit gap was within the clinically accepted marginal gap 120 μm [58, 46]. Some studies even claim superior marginal gap than the metalo-ceramic crowns/gold crowns.

2.9.8. Clinical performance of Procera® AllCeramic crowns

Among all the all-ceramic systems, Procera® AllCeramic system received notable attention in review of article. All the observational report is that, anterior crowns enjoyed the maximum success rate compared to the posterior single crowns. The lowest reported failure rate was less for high fracture strength material like alumina materials like In-Ceram Alumina and Procera AllCeramic material. In longest followed study of Procera® AllCeram crown system, mode of failure of restoration was mainly due to crown fracture compared to all other factors [61].

Karlsson in his study [43] reported that metal fused ceramic bridges had 14.5 % deficiencies in the marginal adaptation and caries and fillings were 8.1 % cases. Deficiencies of the marginal adaptation in some cases were due to retentive problem of fixed partial dentures. Another striking observation in the studies of Walderhaug [95] was that, increased tendency of gingival to bleed around the AllCeramic crowns. These results are in line with the study from Odman [61], who reported that bleeding around AllCeramic crowns were (39 %) more than the contra lateral natural teeth (27 %). From the above reports we can infer that there can be a relationship between the marginal design and gingival health.

2.9.9. Clinical evaluation of Procera® AllCeramic restorations

Clinical success of any restorative material gives us the exact data for predicting the lifetime of the material structure. Furthermore, it also provides data about the influence of oral environmental over the material, and the mode of failure of multilayered prosthesis structure. Long-term clinical evaluation of the success rate of AllCeramic crowns can be comparable to the data of metalo-ceramic crown systems.

Author	Material	No of crowns and bridges	Observation period	Results
Oden A & Anderson *et al.* 1998 [60]	**Crowns** Incisors, Premolars, Molars	100 Crowns	5 years	**94 %** survival rate. - 6 crowns were remade.
Odman. P & Anderson. B 2001 [61]	**Crowns** Incisors, Premolars, Molars	87 crowns	5 and 10.5 years	**97.7% & 92.2%** Success rate 4 crowns fractured.
Fradeani M & *et al.* 2005 [24]	**Crowns** Incisors-Premolars, Molars	50 anterior 155 posteriors	5 year	**96.7 %** survival rate 100 % for anterior **95.15 %** for posteriors
Naert I & *et al.* 2005 [58]	**Crowns** Incisors-Premolars, Molars	300 crowns	0.5 to 5 years	1 crown fractured, 6 % ceramic infractions
Zarone F & *et al.* 2005 [106]	**Crowns** Incisors-Implants	86 crowns	4 years	**98.8 %** success rate. 1 crown lost 1 crown veneer fracture
Walter MH & *et al.* 2006 [98]	**Crowns** Incisors-Premolars, Molars	70 patients 61 anterior 46 posteriors	6 years	**94.3 %** all crowns. 6 crowns fractured
Galindo ML& *et al.* 2006 [27]	**Crowns** Incisors-Premolars, Molars	50 patients 155 crowns	5 and 7 years	**99 %** survival rate. 1 crown fracture

Table 3.1 *clinical evaluations of Procera® AllCeramic crowns and bridges*

From the above data we can infer that Procera® AllCeramic restorations experienced on an average **96 %** of long term success rate It also revealed that the need to replace crown were mainly due to crown fracture. These standards of results are more than what has been specified by Pröbster [69].

3
AIM OF THE STUDY

The aims of the study were:

- The main purpose of this *in vitro* study was to find out the "mean absolute marginal adaptation" of the Procera® AllCeram crown copings.

- To investigate whether the mean absolute marginal discrepancy of Procera® AllCeram crown copings can be influenced by the tooth groups [incisors, molars].

- To investigate the marginal gap value differences depending upon their location within the tooth.

- To investigate whether the cementing media can influence the "mean absolute marginal adaptation" of the Procera® AllCeram crown copings.

4
OUTLINE OF THE STUDY

Outline of this study:

Two right maxillary first molar and two central incisors acrylic model teeth [AG 3 Frasaco, Germany] were prepared for Procera® AllCeram crowns. The teeth were prepared with 0.8 mm chamfer finish line, occlusal preparation of 2.0 mm, and with total convergence angle of 6 degrees. Four prepared resin teeth were embedded into auto-polymerizing resin blocks and duplicated 9 times using silicone-based impression material [Aquasil™, putty& Aquasil™ ultra LV Dentsply DeTrey Germany] to achieve 36 die stone models. 3 models of individual tooth preparation were allotted in to three groups to achieve a total of 12 models. Procera®AllCeram 0.6mm coping of densely sintered alumina were fabricated for 36 models. First group copings were fixed with zinc phosphate cement, **AZ group** [Adhesor®, Spofa Dental] second group were fixed with glass ionomer cement, **AG group** [Kavitan®Cem, Spofa Dental] and third group were fixed with duel cured resin cement, **AR group** [Dual®Cement, Ivoclar Vivadent AG]. Then the absolute marginal gaps of the entire samples were measured using the scanning electron microscope at the margin on four axial surfaces [mid buccal, mid mesial, mid lingual, and mid distal] at the predetermined spots.

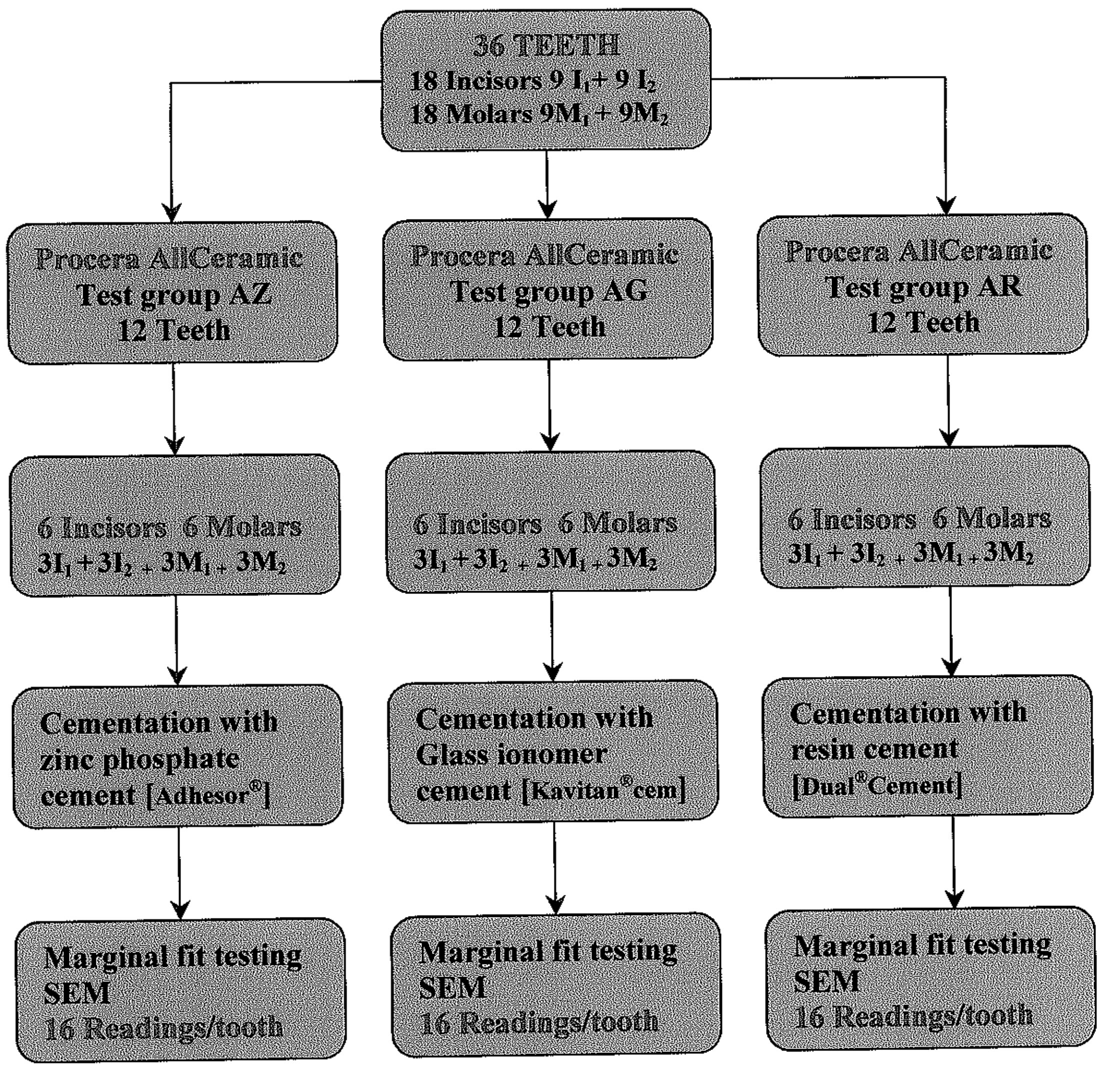


Fig: 4.1. *Flow chart representation of the outline of study*

5
MATERIALS AND METHODS

5.1 Materials:

5.1.1 Typodont teeth set

The two sets of full mouth typodont teeth [Frasco teeth, AG 3 type, Germany] were used. From this, only right maxillary molar and right maxillary central incisors were selected for the preparation of the teeth for AllCeram crowns.

5.1.2 Materials for the impression and die fabrication

Duracrol® Spofe dental a.s.a, Kerr Company, Cernokostelecka, Czech Republic].

It is a self-cured resin material based on methyl methacrylate. It is in powder and liquid form. The custom-made impression trays were prepared using this material.

Aquasil™ Soft putty, Regular set [Dentsply DeTrey GmbH, Konstanz, Germany. Lot no 0701001089].

It is a precision additional silicone material impression material with very high viscosity. This material is based on "Quadra functional" hydrophilic siloxane. They comply with the requirement of ISO 4823 for dental elastomeric impression materials. These materials are mixed at 1:1 ratio of base and catalyst and have a linear dimensional change [ISO] 0.05 %, permanent deformation [ISO] 0.5 %, and detail reproduction of [ADA] <50 µm. Mixing time is 0.30 minute while the working time and final setting time are 1.30 minute and 4.30 minute respectively.

Aquasil Ultra LV, Regular set [Dentsply Caulk, Millford, USA. Lot no 060206].

It is a precision additional silicone material impression material with very high viscosity. This material is based on "Quadra functional" hydrophilic siloxane. They comply with the requirement of ISO 4823 for dental elastomeric impression materials. Aquasil ultra smart wetting improves both wetting on the tooth surface and model detail reproduction. This material has >98.0 %, detail reproduction of <20 µm, and linear dimensional change <0.50 %. The working time is 2.15-2.45 minute, and setting time 5.00 minute from start of mix. The materials are dispensed as gun and cartridge.

Japan stone, EN ISO 6973 Type 4 die stone [Dr Böhme and Schöps Dental GmbH, Goslar, BorsigstraBe]
It is a type 4 dental die stone. This is a synthetic material with exceptionally high edge strength. It is also has thixotropic property. Water: powder ratio is 20ml: 100mg; setting time is 9 -11 minutes. The setting expansion is 0.08 % and the compressive strength is 53MPa.

The distilled water used was "Diluent", Roche Diagnostics. Corp, Indiana Polis USA, Lot no Ch-B, 63325601.

The vacuum mixer used was "Multivac® Type M4-01, Degussa AG, Hanu, Germany. Mixing time used was 60 seconds.

Vibrator used was Type EWL 5442, KaVo, Electro Echnisches work. Germany.

5.1.3 Materials used for die hardening

[**Hardening Bath,** No 1719-2000, and Härtebad-Verdünner No 1719-2100, Renfert GmbH. Industriegebiet, Germany.]
This is a self-hardening plastic solution for dies. It does not form film or deposit over the die surface. Thinner solution is also used to dilute the solution. One or two coating of hardener solution is applied with sable brush on to die surface. This increases the surface hardness, edge strength, and die surface becomes pour free also.

5.1.4 Materials used for the fabrication of the Procera® AllCeramic copings [densely sintered aluminum oxide ceramic, Nobel Biocare, Göteborg, Sweden]

The type of scanner used in this study was model Piccolo no 40, with software provided with system [Procera System C3D, version 1.4; Nobel Biocare AB]. Procera® AllCeramic densely sintered aluminous oxide ceramic are in powder form. The composition is >99,5 % aluminium oxide [Al_2O_3], 500 ppm MgO.

Properties	Values
Appearance	White granules or powder
Melting point	2030°C
Boiling point	2977 °C
Vapour pressure	1mm Hg at 2158 °C
Specific gravity.	4.0
Solubility in water	Negligible
Particle size	<5 μm
Flexural strength	487-699 MPa
Fracture strength	4.48-6 Mpa/$^{1/2}$

Table 5.1: *Physical properties of Procera AllCeram [Source: Procera AllCeram Brochure, Nobel Biocare, Göteborg, Sweden and J Prosthet Dent 2004;92: 557-62]*

5.1.5 Materials used for cementation procedure

Adhesor®, Spofa Dental; CE 0044, A Kerr Company, Cernokostelecka, Czech Republic, Powder Lot no- 1238736-3, Liquid lot no-1343558].

This is zinc phosphate cement luting cement. The main ingredients of the powder are zinc oxide [90 %] and magnesium oxide [10 %]. The liquid contains phosphoric acid, water, and aluminium phosphate. Water content is 33 % of liquid. The setting reaction starts by attacking of phosphoric acid and releasing of the zinc ions. Zinc ions react with the aluminium and phosphoric acid complex and to form zinc-alumino-phosphate gel. Setting time of zinc phosphate cement is between 5 and 9 minutes. The film thickness of zinc phosphate cement is 20μm, while the solubility and disintegration in water is 0.06 wt %.

Kavitan®Cem, Spofa Dental [CE 0044, A Kerr company, Cernokostelecka, Czech Republic, Powder Lot no- 1585904, Liquid lot no-1550335-2].

This is the Type-1 glass inomer cement [*Polyalkenoate cement*]. Glass ionomer cement powder is an acid-soluble calcium fluoroaluminosilicate glass. Lanthanum, strontium, barium are added for radiopacity. The liquid is an aqueous solution of polyacrylic acid in concentration of 50 %. During the setting reaction acid attacks the surface of glass particle. Calcium, aluminum, sodium, and fluorine ions are leached into the aqueous medium. The polyacrylic acid chains are cross-linked by calcium ions and form solid mass. The film thickness of glass ionomer cement is 24 μm, solubility and disintegration in water is 1.25 wt %, and setting time is 7 minutes.

Dual®Cement, [Ivoclar Vivadent AG, Schaan, Liechtenstein], Lot no base G0 6570, Catalyst- GO 6570.

Dual cement is a microfilled, light- and self- curing composite cement used for adhesive cementation of all ceramic crowns. Dual Cement is distinguished for its excellent physical properties, high abrasion resistance, continuous fluoride release, as well as good radiopacity. The monomer matrix consists of urethane dimethacrylate and decandiol-dimethacrylate. The inorganic fillers are silicon dioxide and ytterbium trifluoride. Additional contents are catalysts, stabilizers, and pigments. The total contents of inorganic fillers are 61 wt %. The particle size is between 0.04 and 0.3 μm with a mean grain size of 0.2μm. Setting time is 4-5 minutes and curing time is 40-60 seconds.

5.1.6 Additional materials and equipments used

'Primacryl® Plus'Acrylic resin [clear acrylic] Powder and liquid. Lot no-Liquid: 1475888 Powder: 1322246	Spofa Dental; CE 0044, A Kerr company, Cernokostelecka, Czech Republic,
Diamond burs: 508g, 508F, 801, 830G, 830F, 878G, 878F, 909.	Meisinger, Hager&Meisinger-GmbH,Hansemannstr,Neuss,Germany
'Occlu Plus-Spray'	Hager-Werken GmbH and co. KG, Duisburg, Germany.
Micro brushes	Ivoclar Vivadent AG, Schaan, Liechtenstein Germany
Energy depressive 'X' ray analysis [EDXA] Image 89 k	INCAx – Sight, Oxford Instruments, England UK.
Sputter coating machine Model SC 7640	Poloron make Quarium Technologies Sussex, UK.
Scanning Electron Microscope [SEM] Serial no 440-28-06.	Model-Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK.
Weighing scale, [120 kg max limit]	"Salter" Czech Republic.

5.2 Methods:

5.2.1 Tooth preparation for all-ceramic crown [representative model of the clinical case].

Tooth preparation for all ceramic crowns was done according to the manufacturer's recommendations. The maxillary and mandibular jaws with full complement of teeth were mounted on the phantom jaw. Silicone matrix [Speedex A-silicone material Coltene Whaledent, Sweden] was prepared to aid in the uniform reduction of the tooth. Two maxillary right central incisors [I_1, I_2] and two maxillary right first molar model teeth [M_1, M_2] were prepared for all-ceramic crown using all ceramic preparation kit [Meisinger, Hager&Meisinger GmbH, Hansemannstr, Neuss, Germany].

The 'silhouette technique' [25] of tooth preparation was implemented. The rotary instruments used were in succession from course to fine under constant water spray. The final preparations were of following dimensions, occlusal or incisal reduction approximately 1.5 to 2.0 mm, axial reduction of 1.2 to 1.5 mm with 6 degree occlusal convergence and gingival finish line of 0.8 mm deep chamfer design with uniform width 1.5 mm above the cervical line following the course of the cervical line. Labial surface of the incisors and buccal surface of the molars were prepared with two-plane reduction. All the sharp line angles and edges were smoothened. On molars, occlusal surface were prepared non-anatomically without having the deep areas. Functional cusps were bevelled with 45-degree angle to the long axis of the tooth. Final tooth preparations were finished with 30 μm rotary instruments. The teeth were removed from the jaw and cleaned.

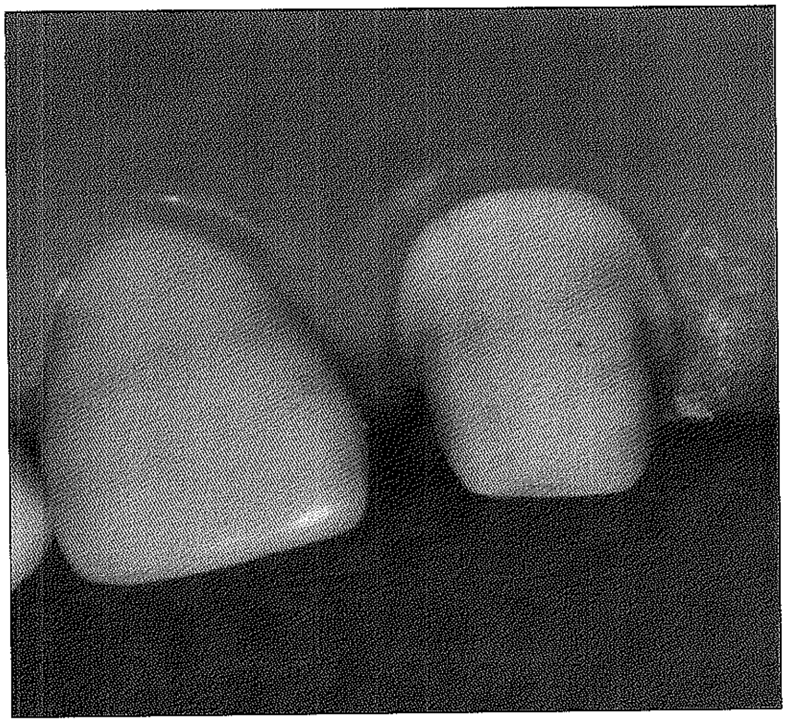


Fig 5.1: *Final tooth preparation buccal and lingual view.*

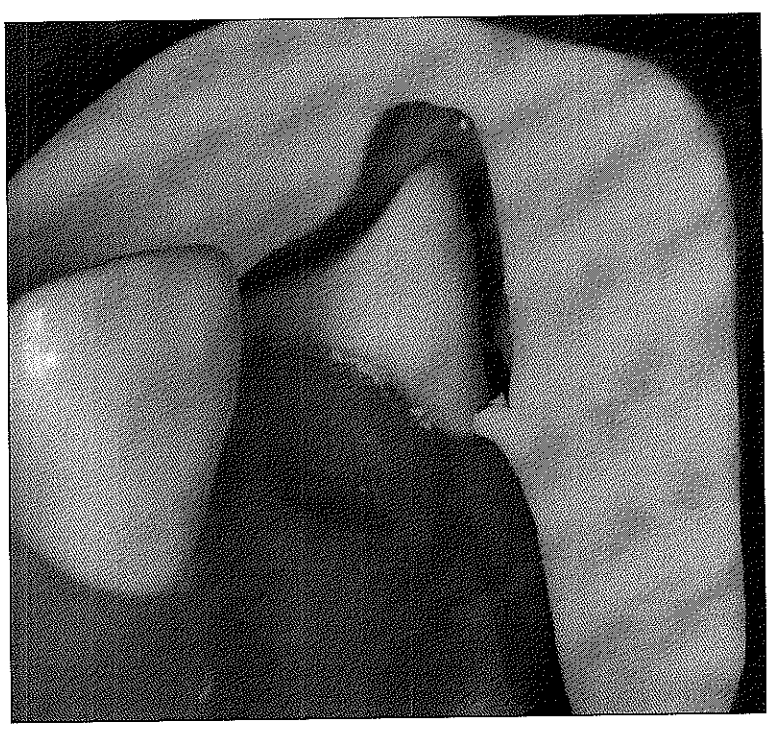


Fig 5.2. *Tooth preparation, view from the proximal surface with 'silicone-matrix'.*

5.2.2 Embedding the prepared teeth into resin blocks.

All four prepared teeth were carefully cleaned. The cleaned samples were isolated at, and 4 mm above and below the cervical finish line using the petroleum jelly [Johnson and Johnson, South Africa]. These samples were embedded onto mixed block of self-cure resin [Primacryl® Plus, Spofa Dental, Czech Republic]. Care was taken to mount all the samples perpendicular to the occlusal plane, and the cervical preparation lines of tooth preparation were 4 mm above the base of resin block. After the setting time of 4 to 5 minutes resin bases were shaped with dimension of 1.5 cm of height and 1 cm width and carefully finished and polished without damaging the tooth preparations using the acrylic trimmer and polisher.

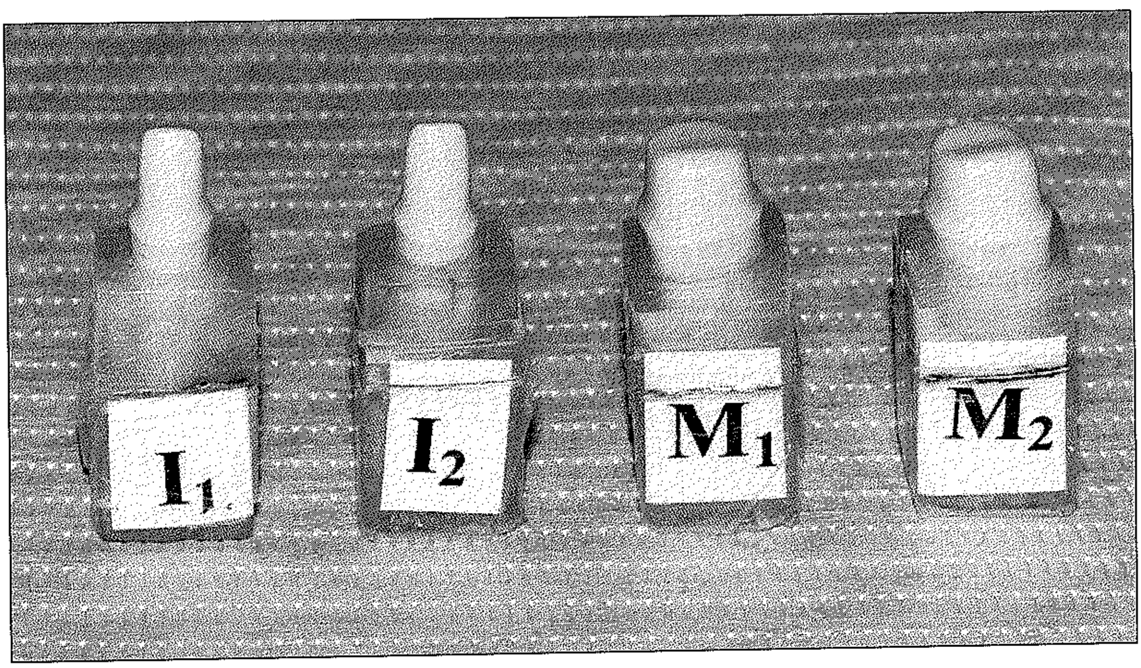


Fig 5.3. Four *original tooth models mounted with acrylic resin base.*

5.2.3 Impressions

Samples were cleaned and dried. The rectangular custom impression trays were prepared using self-cured acrylic resin [Duracrol® Spofe dental, Czech Republic] with dimensions of 2cm width and 2cm height for all the samples. A silicone tray adhesive was applied and dried [Adhasive, Coltène Whaldent, Switzerland]. Two step putty wash technique [Aquasil™ Soft putty and Aquasil Ultra LV, Dentsply DeTrey, Germany.] was employed to take impression of the original models. Equal quantity of the catalyst and base were mixed until uniform colour was obtained. This putty mix was placed into the custom tray and the impressions of the tooth sample were taken and held in position until 5 minutes. These putty impressions were scored 2 mm, using the Bard parker blade no -15 around the tooth imprint. The tray with putty impressions were filled with Aquasil Ultra LV, [Dentsply Caulk, Milford, USA] using the dispenser gun and placed around the tooth samples. The tray was put in place and held without pressure for 5 minutes. After 1 hour, the impressions were sprayed with a surfactant and dried.

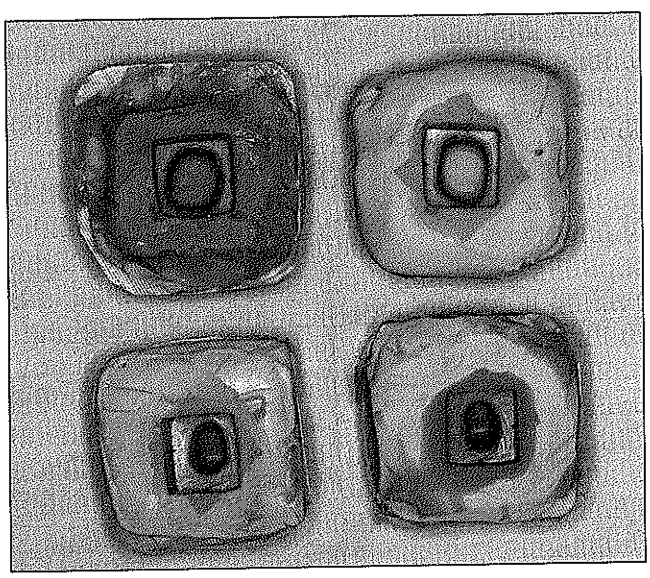


Fig: 5.4. *Custom trays with impressions of the tooth models.*

5.2.4 Fabrication of the dies

The master dies of the original tooth samples were poured using the type 4 die stone [Japan stone, Dr Böhme and Schöps Dental GmbH, Goslar, BorsigstraBe]. These stone powders were mixed with distilled water [Diluent, Roche Diagnostics Corp, Indiana Polis, USA.] in a ratio of 20ml/100gr for 60 seconds using the vacuum mixer [Multivac® Type M4-01, Degussa AG, Germany] mixing time used was 60 seconds, and the mixed diestone was poured into each impression using vibrator [Type-EWL 5442, KaVo, Electro Echnisches work. Germany]. After two hours, the models were separated from the impressions. These models were checked for any defect, and were then coated with the die hardening solution [Hardening Bath, No 1719-2000, and Härtebad-Verdünner No 1719-2100, Renfert GmbH. Industriegebiet, Germany.]. The excess die materials at the base of the models were trimmed.

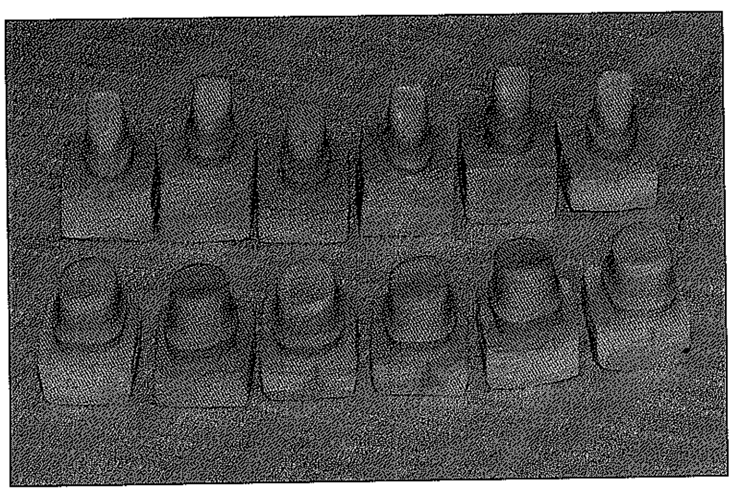


Fig: 5.5. *Master models after the application of the die hardener solution* [Hardening Bath, Renfert ,Industriegebiet, Germany]

5.2.5 Fabrication of the scanning models.

One die model of the each original tooth was selected for scanning the details to digitalize to order the copings. The base of the four models were trimmed to have parallel side from all the side below the chamfer finishing line using the large pear shaped laboratory bur. The areas immediately below the chamfer margins were refined all around the model, so that only margins are prominently seen. Care was taken not to touch the details of the margins.

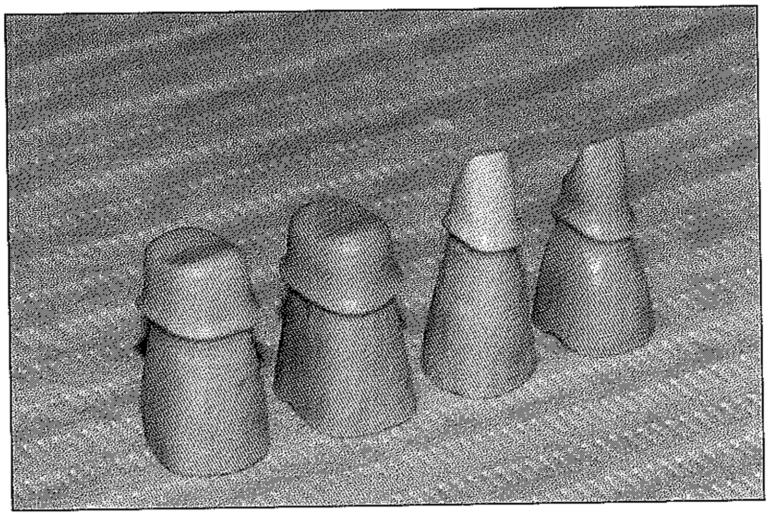


Fig: 5.6. *Modified master die models for the scanning using Procera® Piccolo scanner.*

5.2.6 Ordering the Procera® AllCeramic copings.

The Procera system (Nobel Biocare) was introduced in 1993 from Andersson and Oden for the industrial manufacturing of frameworks in a remote production unit The prepared scanning models of master models were mounted on to the Procera® Piccolo scanner' s model holder at our teaching hospital dental laboratory. Tooth preparations and soft tissue margins were scanned from the master dies by the scanner. Procera® Piccolo [Nobel Biocare, Göteborg, Sweden], which is the tactile [contact] scanner that works by the principle of surface morphology detection. The entire scanning procedure took 6-10 minutes and was controlled from a PC interface with an integrated user friendly, on-screen tutorial.

The scanning data were transferred to the Procera® Software CAD application, where the 3D Computer-Assisted-Designs were finalized. The preparation margins were marked on the computer screen and the AllCeramic coping materials of thickness 0.6 mm were specified. The volume data were compressed and transferred via modem to the production facility, which used the information to calculate the anticipated shrinkage (20 %) and fabricated an enlarged die. The outer surfaces of the enlarged and porous framework were milled to the desired shape after being removed from the die. This was then inserted into the furnace and fired at temperature of about 1550° C. During this cycle, the frameworks shrinked to fit the dimensions of the original working die.

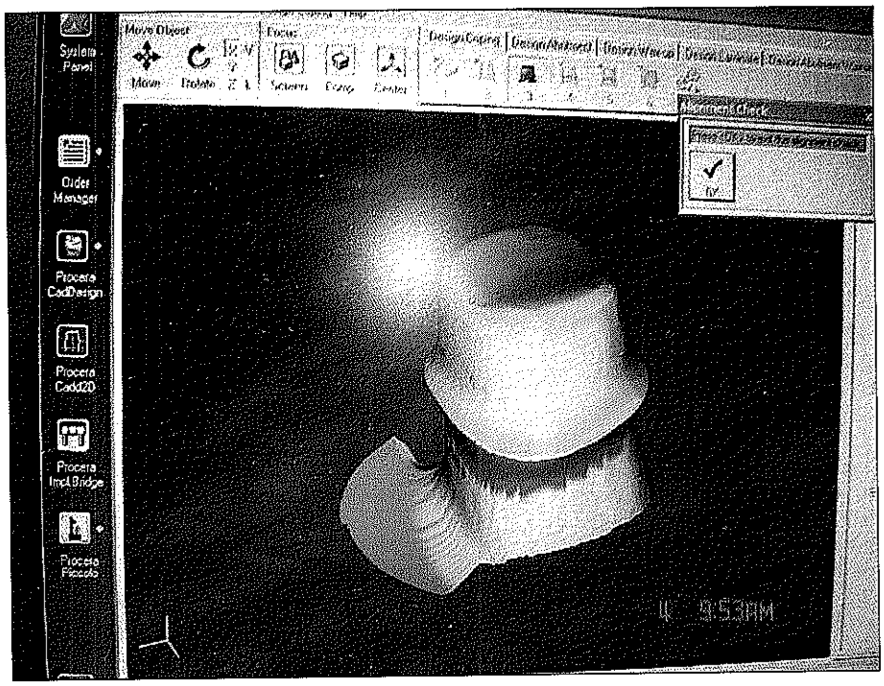


Fig. 5.7:. *Two-dimensional digital refinements of the preparation margin using software.*

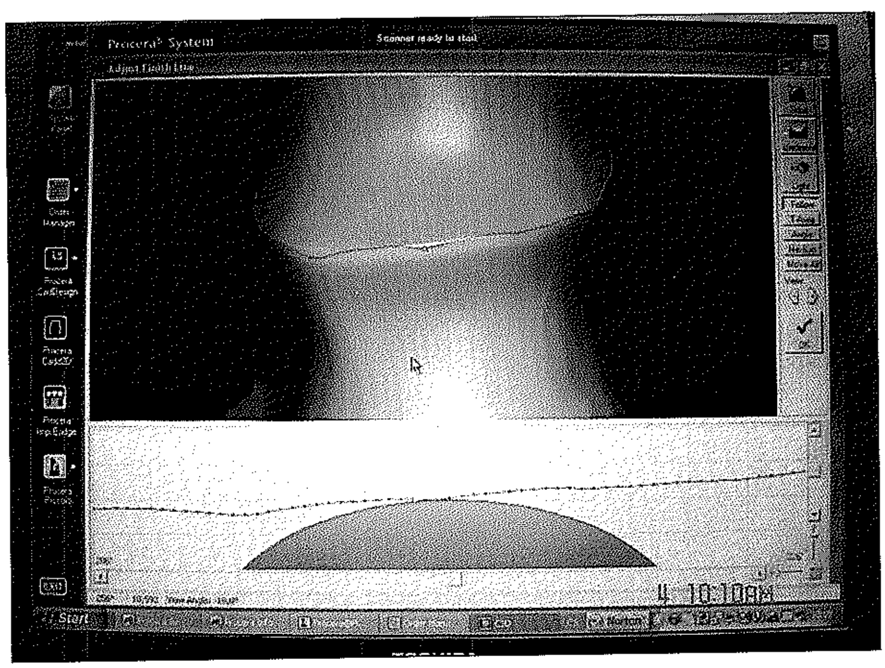


Fig. 5.8: *Initial colour differentiations during digitisation of the scanned model.*

5.2.7 Manual fitting of the Procera® AllCeram copings.

After receiving fabricated copings from Sweden [Nobel Biocare, Göteborg, Sweden], the copings were inspected for deficiencies at the margins and the die stone models of respective teeth groups. Precision fitting adjustments of the frameworks were carried out manually. A surface marker spray (Occlu Plus-Spray, Hager & Werken GmbH & Co. KG, Duisburg, Germany) was used for this purpose. The inner surfaces of the copings were sprayed with a superfine layer, and high spots that prevented perfect sitting were detected and refined by manual grinding using fine-grain 30μm diamond [830F,and 878F, Meisinger] under water coolant. After manual precision fitting, the wall thicknesses of the copings were measured using a measuring calliper. In all test group copings, thickness registered were 0.6 mm.

5.2.8 Cementation procedure of AllCeram copings

36 samples were divided into three groups of 12 teeth AZ, AG and AR respectively. Inner surface of all the copings were cleaned with water and dried with water free and oil free air. For all the samples the areas immediately below the finish line of the die models were isolated using the thin layer of petroleum jelly [Johnson and Johnson, South Africa] carefully to aid in easy removal of the excess cement.

Group AZ = luting with Zinc phosphate cement [Adhesor®, Spofa Dental; A Kerr company, Cernokostelecka, Czech Republic].

The technique used to mix the zinc phosphate was 'frozen glass slab' technique. Powder and liquid were dispensed according to the manufacturer's instructions. Dispensed powders were divided into multiple equal small increments. Each individual increment was then incorporated into liquid for 15 to 20 seconds. Mixing was done on a large surface area of the slab and completed in 90 seconds. During mixing, consistency of the cement was crosschecked by lifting the mixing spatula with cement about 20 mm off the slab. The formed thread snapped back into the slab. This mixed cement was coated into thin layer with mini-brush [Ivoclar Vivadent AG, Schaan, Liechtenstein, Germany] into the fitting surface of the copings. Then the copings were placed on the individual die by rotating the copings from lingual to buccal surface. The static force of 50 N [5.25 kg] was placed using the finger pressure on the weighing scale ["Salter, Czech Republic] for the initial 5 minutes of setting. After the complete setting, excess cement was removed using the explorer. In the same manner, the remaining copings were fixed on to the die models of the group. Care was taken not to damage the margin edge.

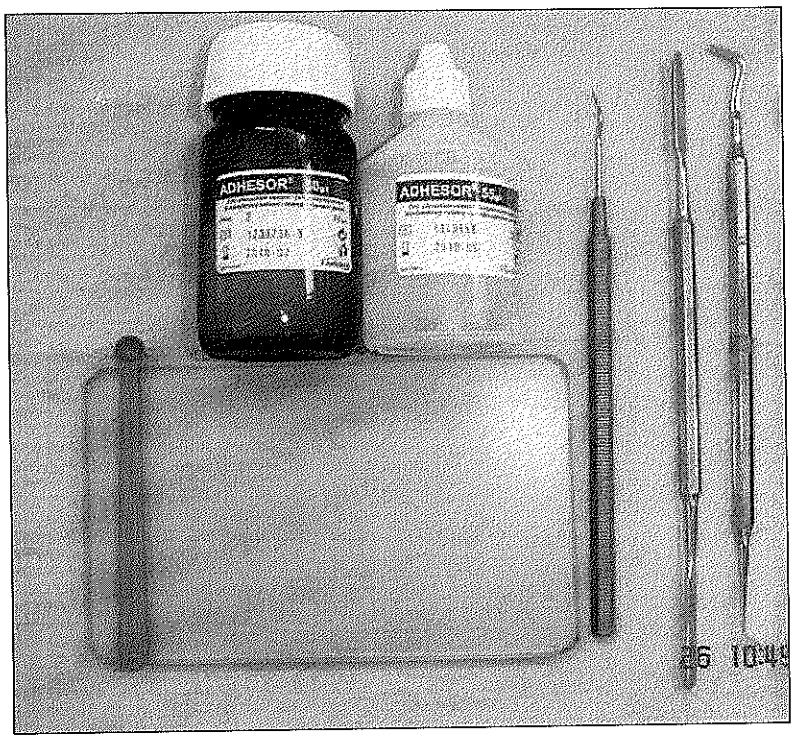


Fig. 5.9: *Armamentarium used during the manipulation of the Zinc phosphate cement [Adhesor®, Spofa Dental; A Kerr company, Černokostelecka, Czech Republic].*

Group AG = Luting with Type 1 glass inomer cement [Kavitan®Cem, Spofa Dental; A Kerr company, Cernokostelecka, Czech Republic]. Powder Lot no- 1585904, Liquid lot no-1550335-2.

Glass ionomer cement is also manually mixed according to the manufacturers instructions. Powder and liquid were dispensed on to the mixing pad. The measured powder was divided into two equal parts and mixed using the plastic spatula. The first increment was incorporated rapidly within 10 seconds and the second increment was mixed for 10 seconds. The mixed cements were coated on to the fitting surface of the coping in thin layer. Then the copings were fitted on to the teeth with lingual to buccal rotations under the static load of 50 N with finger for about 5 to 7 minutes on the weighing scale [Salter, Czech Republic]. After the final setting all the excess cements was removed using the explorer. In the same manner the remaining copings was fixed on to the die models of the group.

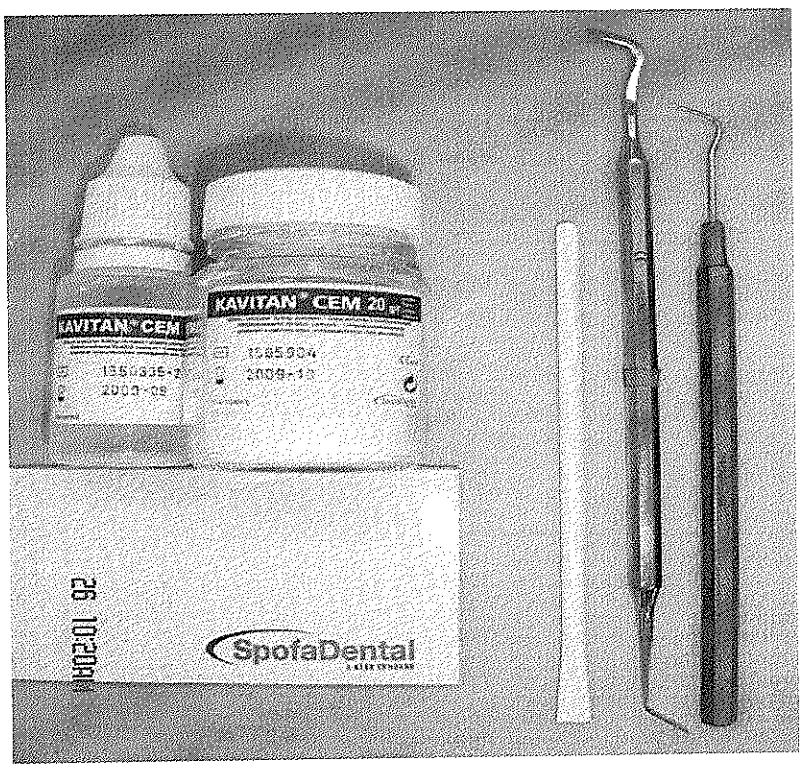


Fig. 5.10: *Armamentarium used during the manipulation of the Glass ionomer cement [Kavitan®Cem, Spofa Dental; A Kerr company, Černokostelecka, Czech Republic.*

Group AR = luting using the Resin cement [Dual®Cement, [Ivoclar Vivadent AG, Schaan, Liechtenstein], Lot no base G0 6570, Catalyst- GO 6570.

The cement used was two-component dual cured cement. The dual cement was dispensed to equal length on to the mixing pad. Without exposing the cement to direct sunlight or bright light the components were manually mixed with plastic spatula to uniform colour and spread over a large area on the mixing pad to prevent air entrapment. Then a thin layer of the cement was applied to the fitting surface of the copings. The copings with cement were seated onto the die models with rotation from lingual to buccal surface. The coping was held in place under static force of 50 N using fingers on the weighing scale [Salter, Czech Republic]. Excess cement was removed quickly by wiping with cotton pellet. The curing light was used to light cure the cement around the margins for about 40-60 seconds. The final checking of the margins for excess cements was done using the explorer. In the same manner the remaining copings were fixed on to the die respective models of the group.

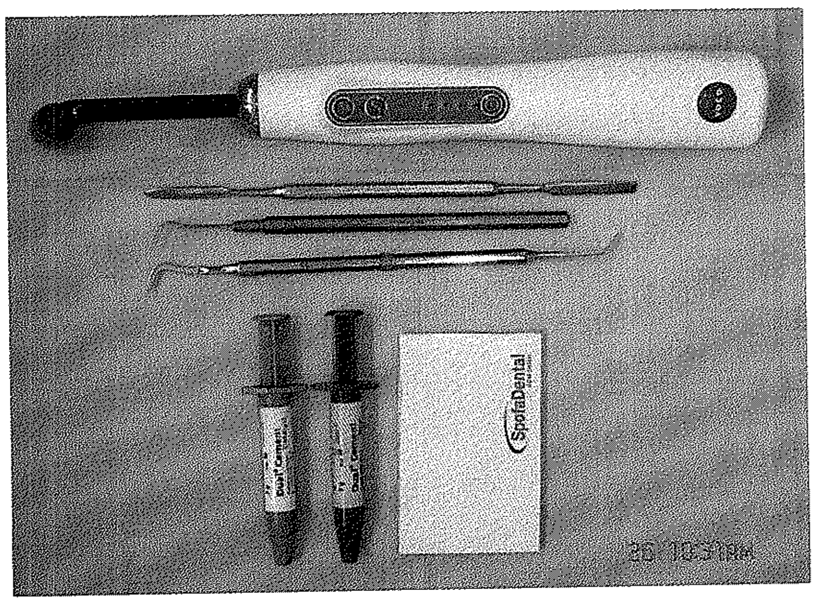


Fig: 5.11: *Armamentarium used for the manipulation of the resin cement Dual® Cement, [Ivoclar Vivadent AG, Schaan, Liechtenstein]*

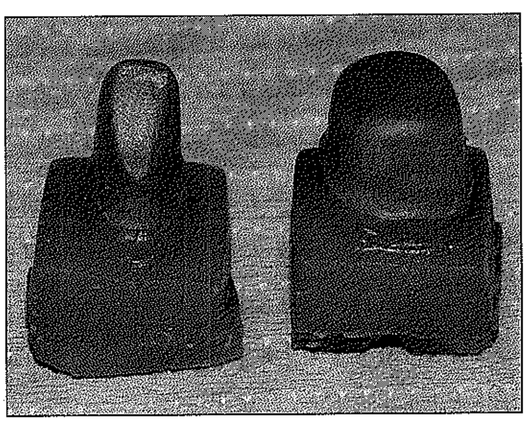
5.2.9 Marking the pre-determined measuring area

For marginal fit measurement using scanning electron microscope, the entire samples were marked at predetermined measuring areas. These points were selected at the centre of the respective axial surface i.e. namely mid-buccal, mesial, lingual and distal. These markings were transferred using the flexible measuring scale to the other samples of the same tooth. The markings were registered on to the samples by scoring parallel line below the finish line and also by marking on to the sample using indelible pen.

5.3 Experiments conducted

5.3.1 Determination of cement space distribution

To know the distribution pattern of the cement space 50 µm incorporated during designing and manufacturing procedure of Procera® AllCeram coping we have conducted an experiment. Single coping of the original model was randomly selected. Copings were filled with the A-silicone low viscosity material [A-Basic® Betasil vario, Omicron Dental GmbH, Schlosserstr] and fitted on to the original tooth preparation model. The copings were fitted against static finger pressure 50 N till the setting time. Excess material around the finish line was removed using a new BP blade no 11. Finally, the coping was removed from the teeth and the thin layer of A-silicone from the fitting surface of the coping was separated, and transferred onto the stone model of the same tooth. In this manner we could visually inspect and appreciate the uniformity of the cement space. This experiment was done before the cementation procedure of the copings.



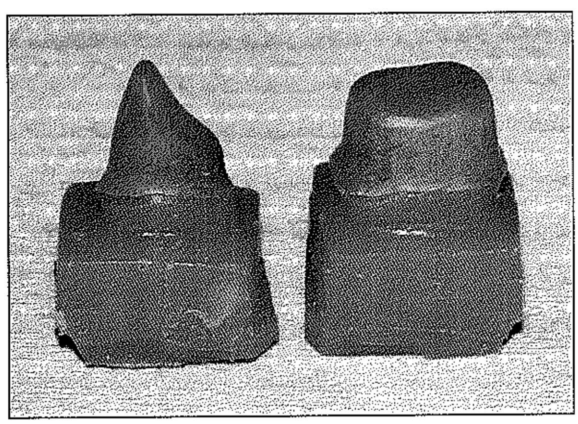


Fig. 5.12 & 5.13. *A-silicone cement space replica on silicone tooth model. Note the uneven thickness of the silicone material.*

5.3.2 Microscopic Surface analysis and chemical composition testing of Procera® AllCeram coping

Surface analysis of the Procera® AllCeram coping were conducted using the scanning electron microscope [Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK.]. The selected samples were sputter coated [Model SC 7640, Poloron make Quarium Technologies Sussex, UK] with gold atoms. This was done to make the non-metallic aluminum oxide and die stone samples electrically conductive. The samples were then placed into the SEM sample holder and analysed for the structural details of sintered materials. The surfaces of the coping were randomly selected in SEM. On examination of the surface of the copings at 10,000 X magnification we found that the molecular size of an aluminum oxide was about 5 μm, and the surfaces were pore free and the molecules were very closely packed. This also confirmed the density of the aluminum oxide sample after sintering at high temperature.

Energy depressive 'x' ray analysis [EDXA] were conducted to know the chemical composition of the Procera® AllCeram coping. EDXA were conducted at mage 89 k [INCAx – Sight, Oxford Instruments, England UK] Results are depicted in Fig. 5.15.

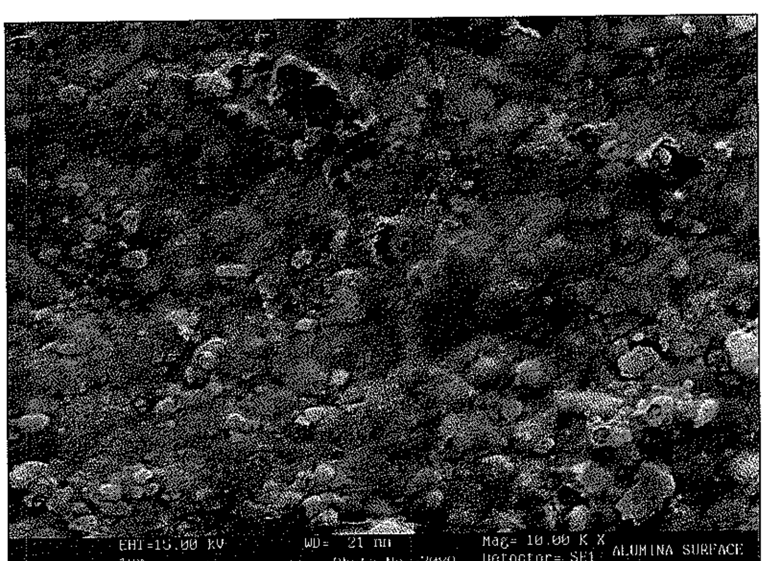


Fig.5.14. *Microstructure of densely sintered aluminum oxide [Al_2O_3] scanning electron microscope picture*

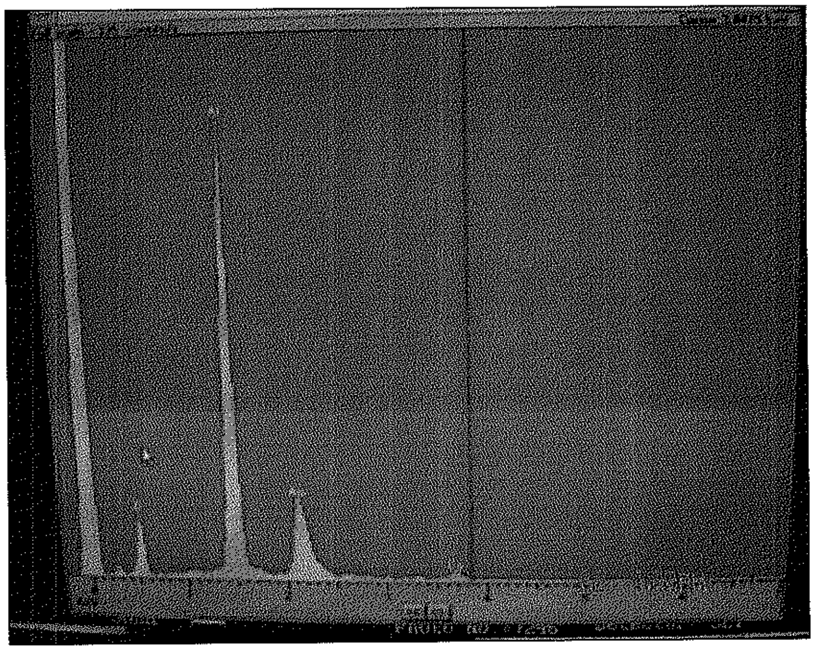


Fig.5.15. *Energy dispersive 'x' ray analysis [EDXA] of densely sintered Al_2O_3 copings*

Test Result: **97.49 % of Al_2O_3 , 2.51 % of CaO.**

5.3.3 Microscopic sample preparations

The die models with the copings are electrically non-conductive samples. All the samples were cleaned meticulously. Then all the samples were kept inside the sputter coater to coat the surface of the samples in groups.

Sputter coater uses argon gas and a small electric field. The samples were placed in a small chamber that was at vacuum. Argon gas was then introduced and an electric field was used to cause an electron to be removed from the argon atoms to make ions with a positively charged. Positively charged argon ions were attracted towards the negatively charged gold foil and knocked the gold foil repeatedly like sand in the sandblaster. Eventually all the gold ions settled onto the surface of the samples producing the gold coating. The gold coating thickness required for SEM was about 50 to 300 A°. Total duration for sputter coating was about 4 to 5 minutes.

5.3.4. Measurement of marginal fit in Scanning electron microscope [SEM]

Scanning electron microscope [SEM] used in this study was [Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK]. All the sputtered samples were firmly mounted onto the sample holder stage of SEM with the help of electrically conductive adhesive tape. All the samples were numbered for identification purpose and placed in such a way that buccal surface of the samples faced perpendicular to the electron gun of the SEM. Then the chamber of the SEM was closed with the samples and fastened. Then the vacuum pump was started to create the vacuum.

SEM uses electrons instead of light to form an image, a beam of electrons are produced at the top of the microscope by heating a metallic filament. The electron beam hits the samples on the sample stage of SEM, and backscattered or secondary electrons are ejected from the sample. Detectors in the chamber collect these secondary electrons, and convert them in to a signal that is sent to viewing screen similar to the one in an ordinary television. By changing the size of the electron beam scans, on the sample, the magnification can be changed. The smaller the area of the electron beam scan, the higher the magnification obtained.

First, the indented predetermined measuring point on the particular axial surface was located at 50 X magnifications in SEM screen. The four reading spots were selected around the mid axial surface, at an interval of 200 µm. Then those points were magnified to the level of visually identifiable level of demarcating the margins of finish line, alumina coping, and the gap. The electronic measuring bar of this SEM provides the actual distance in microns at this particular spot by taking actual magnification factor into account. Care was taken to align the measuring spot at 90 degrees to each other, in vertical direction across the gap. All the measurements were taken one-dimensionally across the gap filled with luting cement, from external margin of the copings to margin of the chamfer line. The same procedures were repeated till we had four-readings per surface, and finally the remaining axial surface were subjected to similar measurement.

Measuring procedures were repeated on all remaining samples of the other groups. A single operator made all the measurements from the external edge of alumina coping to the finish line. Accuracy of the digital calibration scale of microscope was reconfirmed and found to be 0.2 microns accurate.

All the readings were noted down group wise in computer excel sheet [Microsoft office 2003, Microsoft USA]. There were total of a 16 readings per tooth. The four measurements of marginal discrepancies on each axial surface were averaged to obtain a single measurement for each wall. The four mean axial surface measurements for each tooth were used to calculate an overall mean gap size per specimen.

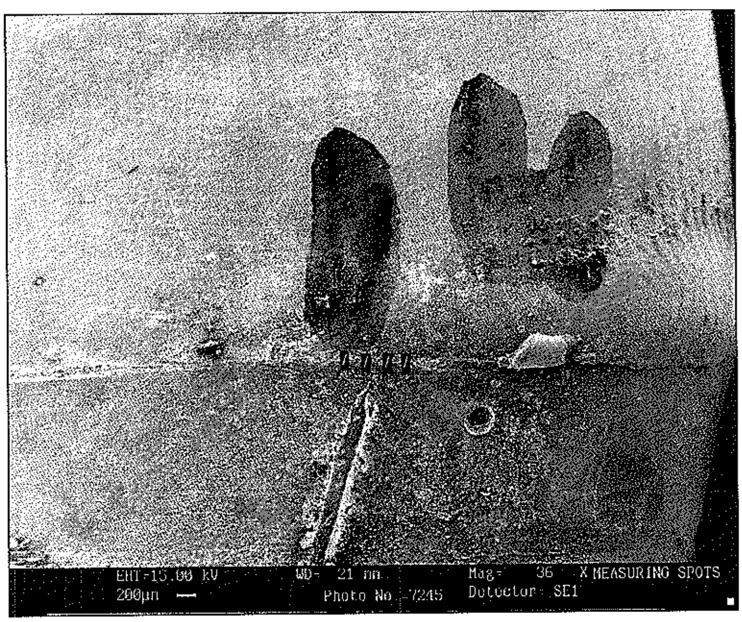


Fig. 5.16. *Marginal discrepancy, distance between the external surface of the coping margin and the preparation finish line, was measured in µm from SEM. Representative SEM photomicrograph [50* µm *] with arrows showing the potential measuring sites of marginal discrepancy.*

<u>**Group AZ**</u>

Fig. 5.17. a, b, c, d: SEM measurement sample pictures

[Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK]

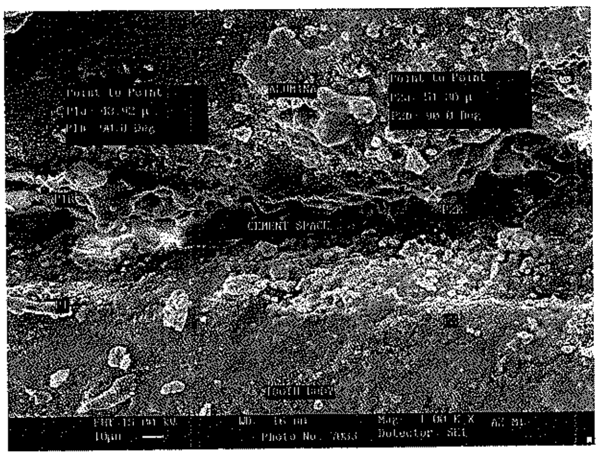


Fig. 5.17a.

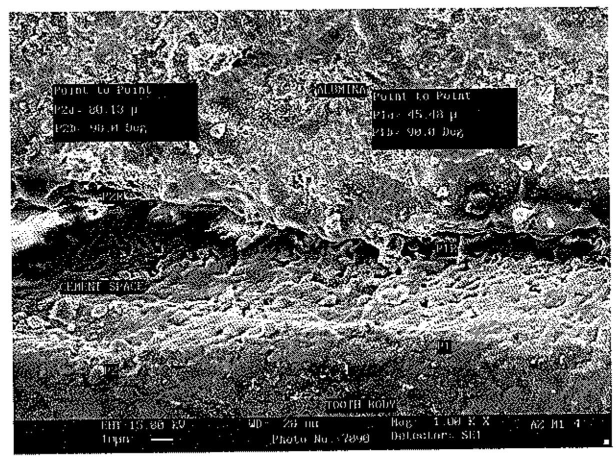


Fig. 5.17b.

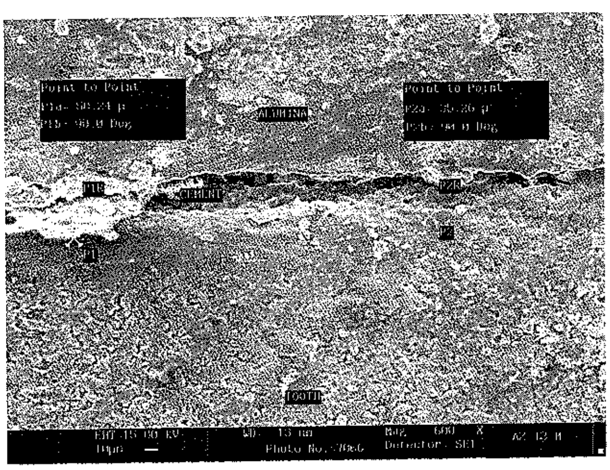


Fig. 5.17c.

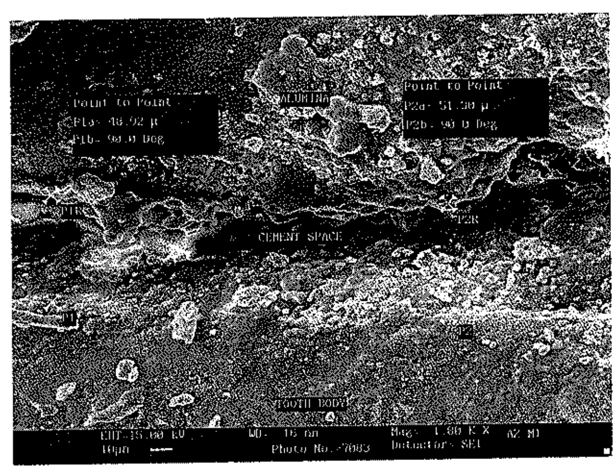


Fig. 5.17d.

Group AG

Fig. 5.18 a, b, c, d: SEM measurement sample pictures

[Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK]

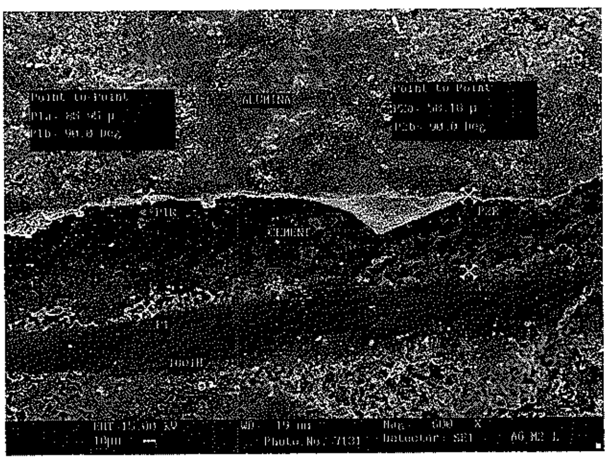


Fig. 5.18a.

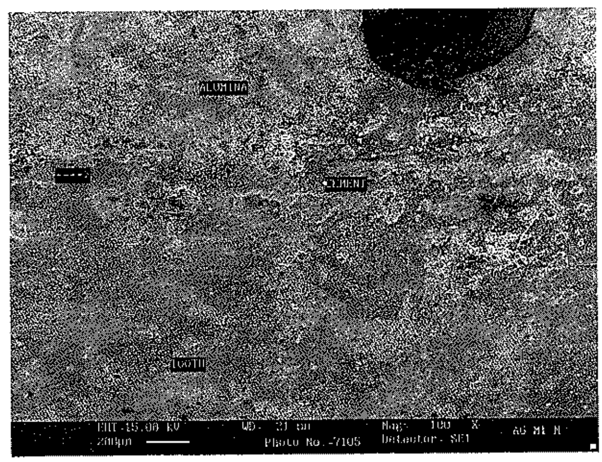


Fig. 5.18b.

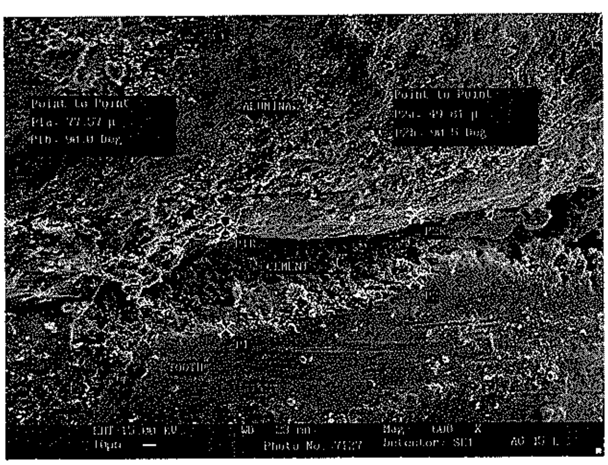


Fig. 5.18c.

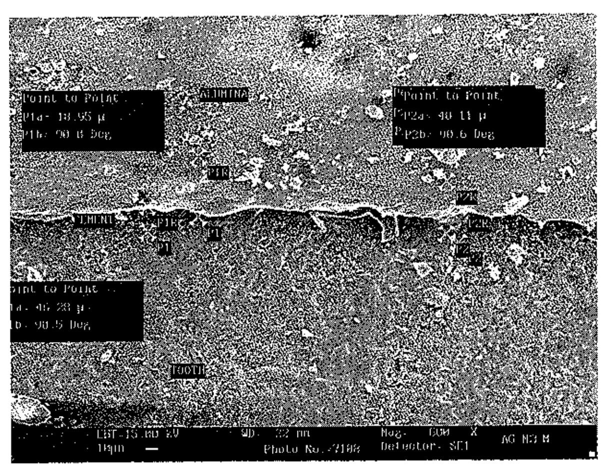


Fig. 5.18d.

<u>**Group AR**</u>

Fig. 5.19 a, b, c, d: SEM measurement sample pictures

[Leica Leo S 440 I, Leica Cambridge Ltd, Cambridge, England, UK]

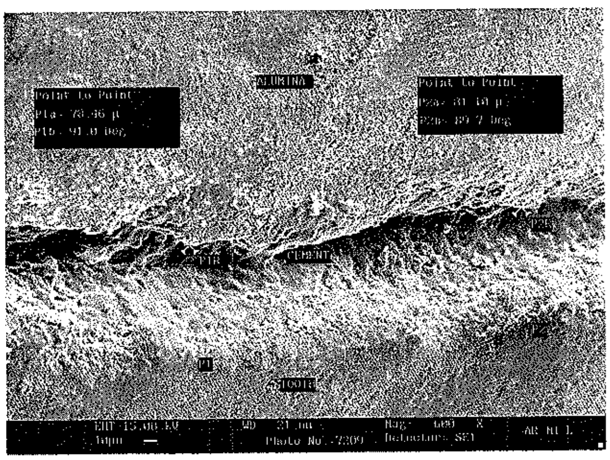


Fig. 5.19a.

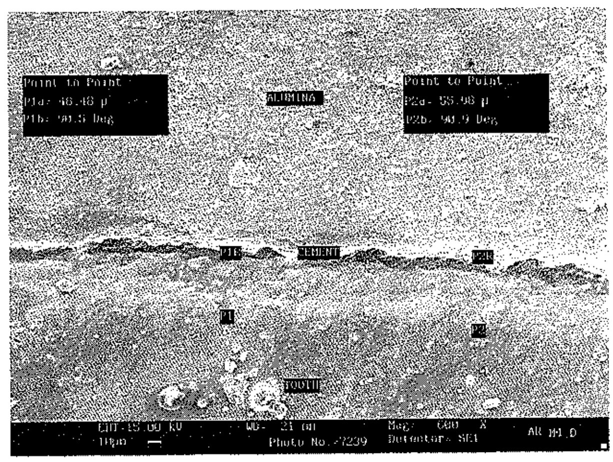


Fig. 5.19b.

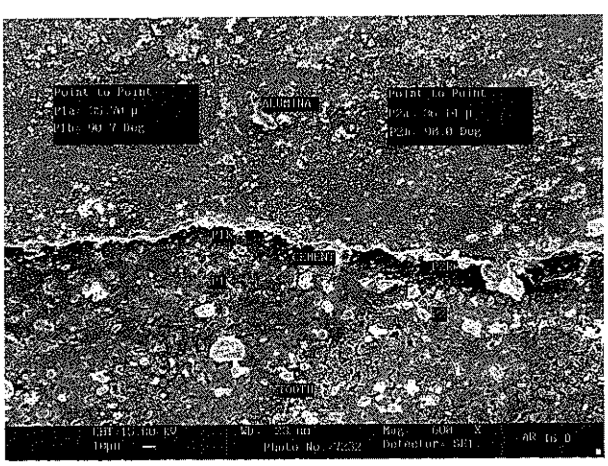


Fig. 5.19c.

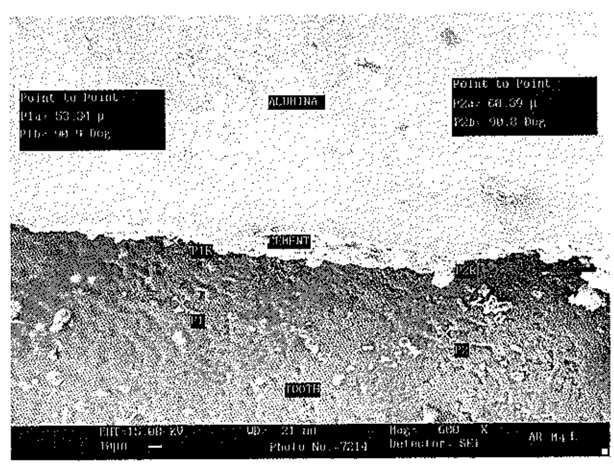


Fig. 5.19d.

5.3.5. Method of Statistical analysis.

The following methods of statistical analysis were used in this study.

The results were averaged (mean + standard deviation) for each parameter. It has been presented in Tables and Figures.

Mann Whitney U test was applied to find out the significant difference between two independent groups. The formula used is follows:

$U = n_1 n_2 + \frac{n_1(n_1 - 1)}{n_2(n_2 - 1)} - \sum R_i$ Where R=Rank order assigned to each value

Kruskal Wallis test was applied to find out significant difference between the study groups. The formula used is as follows:

$$H = \frac{12}{N(N-1)} \sum_{j=1}^{k} \left[\frac{\sum R_i^2}{n_j} \right] - 3(N-1)$$

In the above equation, $\sum_{j=1}^{k} \left[\frac{\sum R_i^2}{n_j} \right]$ indicates that for each of the K groups, the sum of the ranks is squared and then divided by the number of subjects in the group.

In all above test p value less than 0.05 was taken to be statistically significant. The data was analysed using SPSS package.

6
RESULTS

6. Results

6.1 Results of statistical analysis

The strategy used for assessing the marginal gap measurements were through data calculation with direct Scanning Electron Microscopy [SEM] imaging. The four mean axial surface measurements of individual tooth were used to calculate an overall "mean marginal gap" for each tooth. These mean measurements were used to compare the statistical significance [$p< 0.05$]. Evaluation of marginal accuracies usually leads to a non-symmetric distribution of data. This is due to left side of the scale being limited by natural zero point. Thus a positive skew distribution of the data results. The use of non-parametric procedures is recommended when there is evident non-symmetric distribution of data.

The statistical calculation was performed to assess the effect of tooth group variation [Incisors and Molars], different axial surfaces [Mid- buccal, mesial, lingual, distal] and luting agents over the mean marginal adaptation of the Procera® AllCeram copings. In this *in-vitro* study the effect of three factors were studied independently. Out of this, two factors were between–copings [luting agents and tooth group], and another one was within coping [axial surface]. The incorporation of additional parameters was included in this experiment to specify heterogeneity in covariance structure. Therefore, a different covariance matrix was assumed for each combination of the "between-coping" factors. Statistical analyses within and among the groups to find out the significance were made using the Kruskal–Wallis test and Mann–Whitny test [$p< 0.05$]. All the testing has been done at 95 % confidence interval for mean value.

Results:

Mean absolute marginal distance between external surface of chamfer finish line and external surface of Procera® AllCeram copings were obtained for individual tooth sample using direct scanning electron microscopy [SEM] readings. These mean values were obtained from all the four axial surfaces namely mid-buccal, mesial, lingual and distal average value readings.

Group	Tooth	N	Mean	Standard Deviation	Median	Min	Max	Z Value	'p' Value
AZ	Incisors	6.0	59.0	13.0	60.0	42.4	73.2	.200	.240
	Molars	6.0	48.8	11.7	50.4	30.6	65.0		
AG	Incisors	6.0	37.9	13.5	34.9	23.3	57.6	-1.281	.240
	Molars	6.0	27.0	9.4	27.0	17.1	41.8		
AR	Incisors	6.0	44.4	7.1	44.3	32.4	52.6	-.801	.485
	Molars	6.0	50.2	10.8	45.7	39.2	65.3		

Table.6.1: *Intra-group data comparison of "mean absolute marginal adaptation" of incisors and molars.*

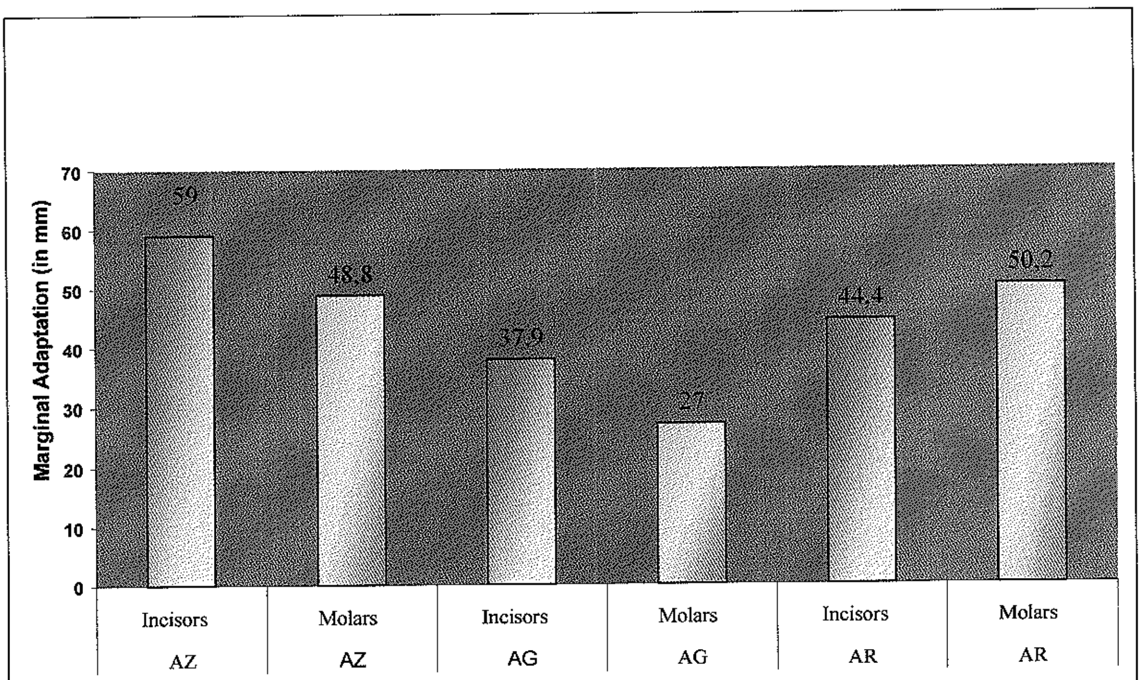


Table 6.1(A): *Comparison of "Mean Absolute Marginal Adaptation" of incisors and molars and between study groups.*

Mean absolute marginal discrepancy of the intra group variance was tested for global significance value of $p< 0.05$ in between incisor and molar. In all the groups, we did not find any significance difference between incisors and molars. But incisors demonstrated the higher marginal discrepancy value compared to molars in all except AR group. Values are represented in table no 6.1.

Group	Tooth	N	Mean	Standard Deviation	Median	Min	Max	Z Value	'p' Value
AZ	Incisors	6	85.4	31.5	80.6	55.0	133.6	-1.922	.065
	Molars	6	49.2	17.7	53.3	21.5	66.4		
AG	Incisors	6	44.3	25.7	49.2	.0	73.8	-1.223	.240
	Molars	6	23.6	27.6	16.8	0.0	63.8		
AR	Incisors	6	36.7	13.0	37.2	19.9	50.5	-.320	.818
	Molars	6	43.4	16.2	41.5	24.5	72.7		

Table 6.2: *Data comparison of marginal adaptation on "mid-buccal" surface between incisors and molars and between the groups.*

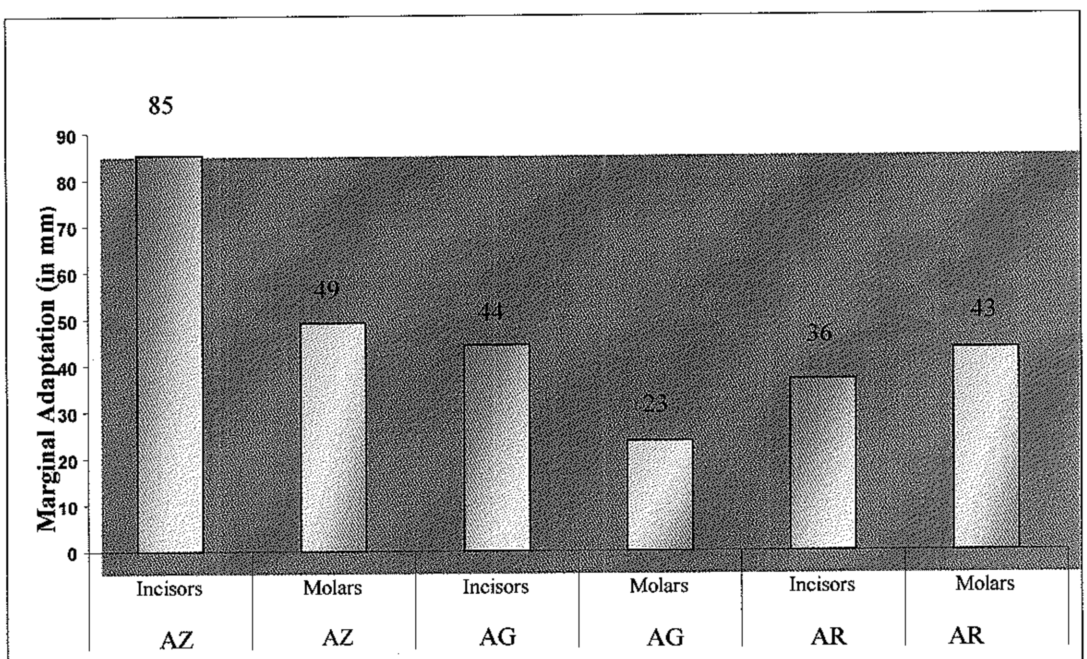


Table 6.2 (A): *Comparison of marginal adaptation on mid-buccal surface between incisors and molars and between groups.*

Individual axial surface marginal discrepancies were compared on mid-buccal surface in between incisors and molars. We did not observe any significant difference in all groups at $p < 0.05$.

Group	Tooth	N	Mean	Standard Deviation	Median	Min	Max	Z Value	'p' Value
AZ	Incisors	6	50.8	18.3	49.8	29.8	73.6	-.641	.589
	Molars	6	41.8	17.9	38.9	21.5	73.3		
AG	Incisors	6	32.8	20.4	32.5	9.1	58.1	-.320	.818
	Molars	6	27.7	18.6	28.6	3.7	58.2		
AR	Incisors	6	40.6	13.1	40.1	26.1	62.5	-.320	.818
	Molars	6	47.7	26.0	41.8	23.3	90.6		

Table 6.3: *Data comparison of marginal adaptation on "mid-mesial" surface between incisors and molars and between the groups.*

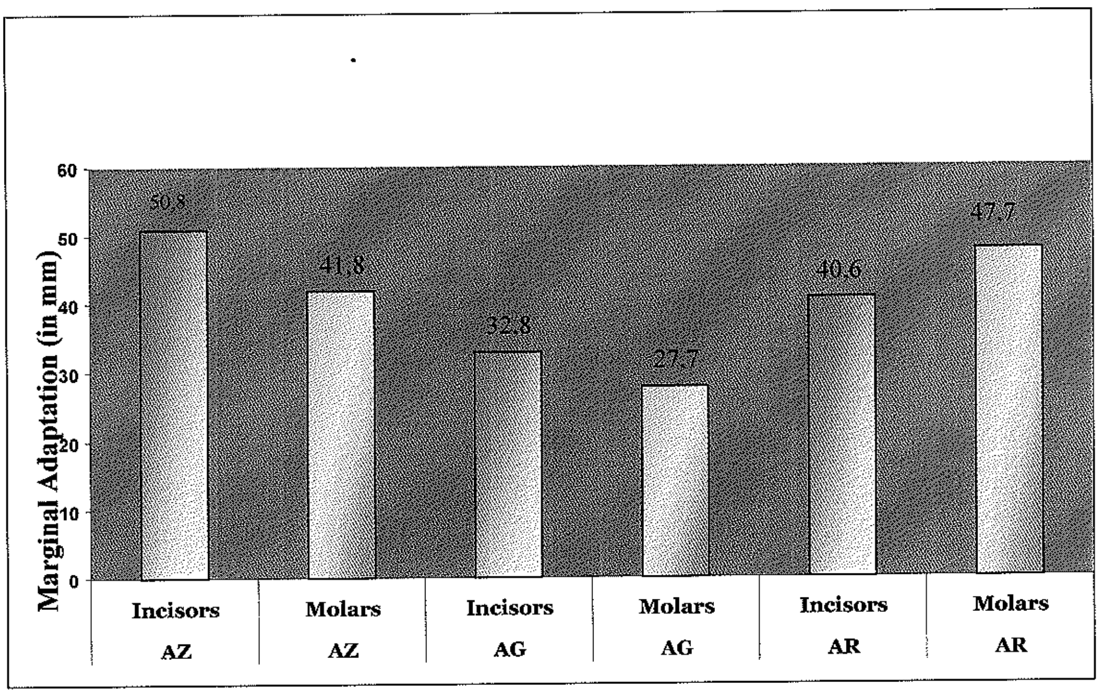


Table 6.3 (A): *Comparison of marginal adaptation on mid-mesial surface between incisors and molars and between groups.*

Individual axial surface marginal discrepancies were compared on mid-mesial surface in between incisors and molars. We did not observe any significant difference in all groups at $p < 0.05$.

Group	Tooth	N	Mean	Standard Deviation	Median	Min	Max	Z Value	'p' Value
AZ	Incisors	6	46.4	12.4	45.7	30.2	60.5	.000	1.000
	Molars	6	47.1	14.2	51.8	27.4	61.3		
AG	Incisors	6	36.3	19.0	35.6	16.7	63.7	-1.281	.240
	Molars	6	23.4	18.5	18.4	10.7	60.1		
AR	Incisors	6	60.8	36.1	42.1	33.5	107.8	-.801	.485
	Molars	6	59.8	10.6	61.0	43.0	73.3		

Table 6.4: *Data comparison of marginal adaptation on "mid-lingual" between incisors and molars and between the groups.*

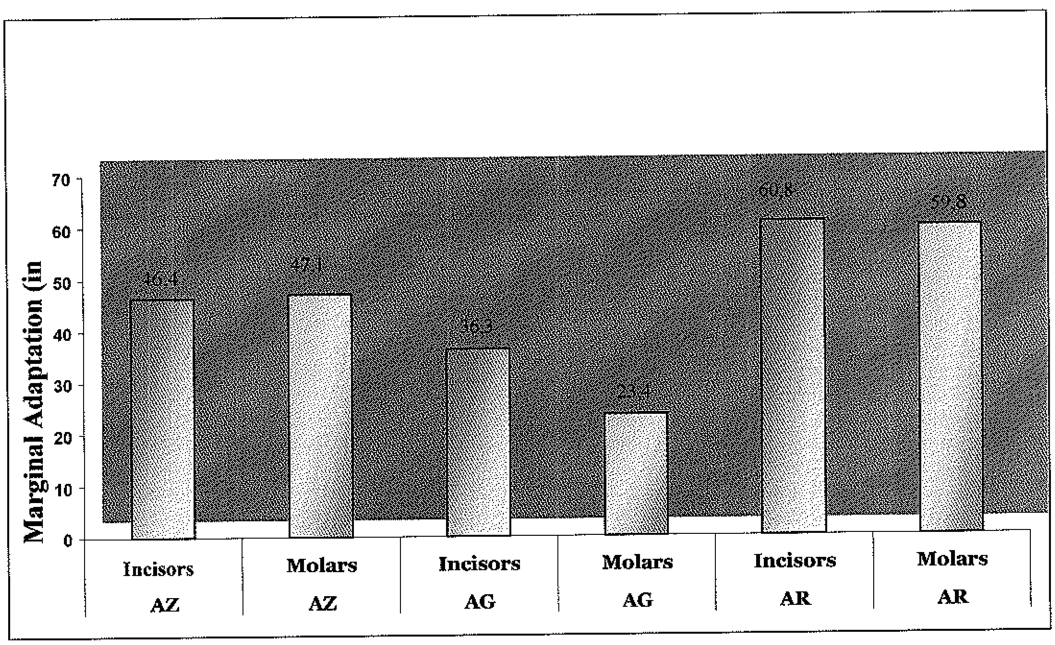


Table 6.4 (A): *Comparison of marginal adaptation on mid-lingual surface between incisors and molars and between groups.*

Individual axial surface wise, marginal discrepancies were compared on mid-lingual surface in between incisors and molars. We did not observe any significant difference in all groups at $p < 0.05$.

Group	Tooth	N	Mean	Standard Deviation	Median	Min	Max	Z Value	'p' Value
AZ	Incisors	6.0	53.4	13.7	53.3	34.3	75.8	-.480	.699
	Molars	6.0	57.3	13.3	53.6	41.8	78.5		
AG	Incisors	6.0	38.4	16.5	41.2	14.5	59.9	-.480	.699
	Molars	6.0	33.3	16.1	27.4	16.0	57.7		
AR	Incisors	6.0	39.7	16.0	37.1	21.5	63.9	-1.441	.180
	Molars	6.0	50.4	4.7	52.3	43.0	54.3		

Table 6.5: *Data comparison of marginal adaptation on "mid-distal" Surface between incisors and molars and between the groups.*

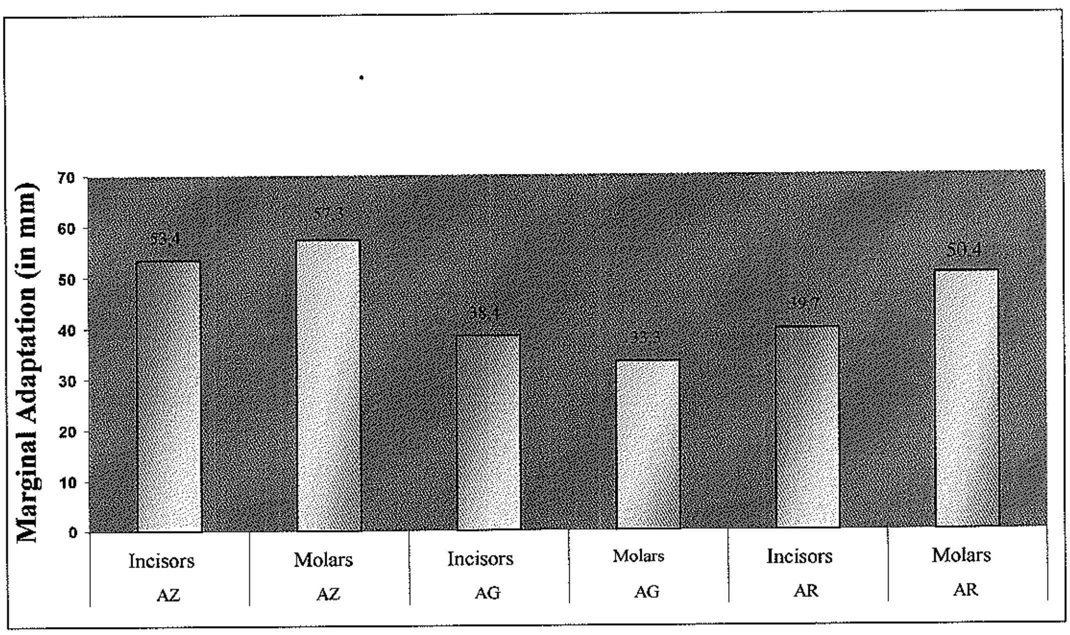


Table 6.5 (A): *Comparison of marginal adaptation on mid-distal surface between incisors and molars and between groups.*

Individual axial surface marginal discrepancies were compared on mid-distal surface in between incisors and molars. We did not observe any significant difference in all groups at $p < 0.05$.

Group	N	Mean	Standard Deviation	Median	Min	Max	Chi Value	P Value
AZ	12	67.29	30.82	61.15	21.49	133.55	8.745	**.013**
AG	12	33.93	27.61	38.86	0.00	73.78		
AR	12	40.07	14.43	41.54	19.94	72.72		

Table 6.6: *Comparing the mean marginal adaptation on mid-buccal axial surface between the groups*

Surface	Comparison	Z Value	P Value
Mid-buccal margin	Resin cement V/s Glass ionomer cement	-0.289	0.799
	Resin cement V/s Zinc Phosphate	-2.656	**0.007**
	Glass ionomer cement V/s Zinc Phosphate	-2.430	**0.014**

Table 6.6 (A): *Mean absolute marginal adaptation comparison among the inter group.*

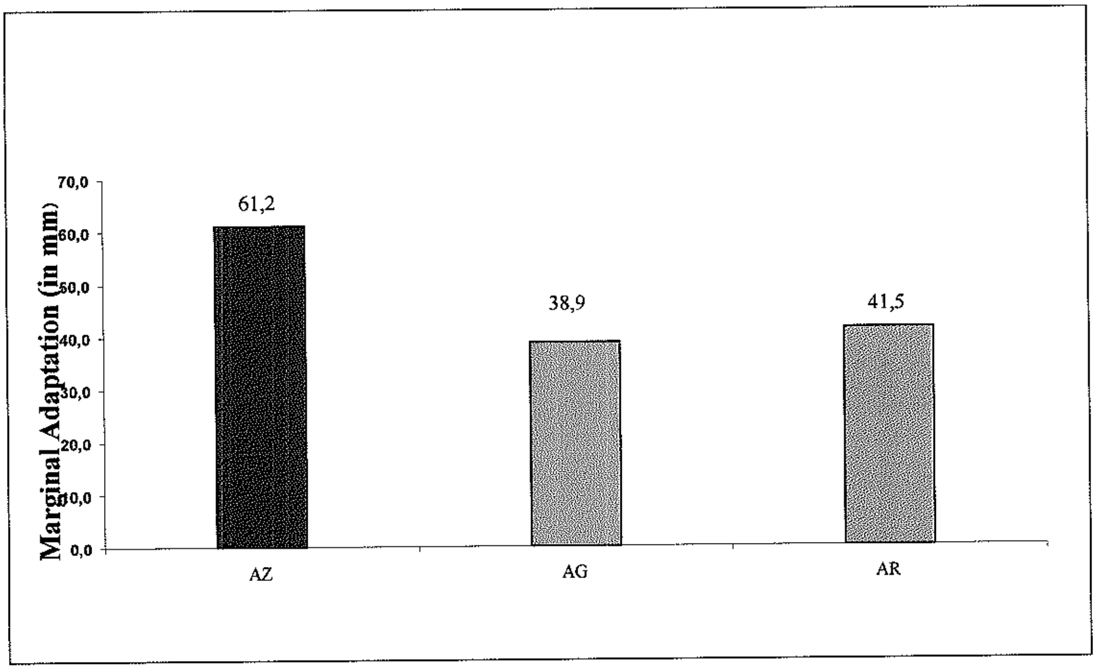


Table 6.6 (B) *Comparing the median marginal adaptation on mid-buccal surface between the groups.*

The comparison of the mean absolute marginal discrepancy of the individual study groups on mid-buccal surface, revealed the significant difference ($p = 0.05$) among the groups.

Specific luting media comparison on the mid-buccal surface showed that, resin cement V/s zinc phosphate cement, and glass ionomer cement V/s zinc phosphate showed that significantly wider marginal discrepancy compared to resin Cement V/s glass ionomer cement

Group	N	Mean	Standard Deviation	Median	Min	Max	Chi Value	p Value
AZ	12	46.28	17.90	41.60	21.49	73.60	4.605	.100
AG	12	30.28	18.81	30.41	3.75	58.19		
AR	12	44.13	19.98	40.77	23.29	90.58		

Table 6.7: *Comparing the mean marginal adaptation on "mid-mesial" axial surface between the groups*

Surface	Comparison	Z Value	p Value
Mid-mesial margin	Resin cement V/s Glass ionomer Cement	-1.617	0.114
	Resin cement V/s Zinc phosphate	-0.346	0.755
	Glass ionomer cement V/s Zinc phosphate	-2.021	0.045

Table 6.7 (A): *Inter group comparison of Mean marginal adaptation*

The comparison of the mean absolute marginal discrepancy of the individual study group on mid mesial surface revealed no significant difference (p = 0.05) among the groups.

Specific luting media also did not reveal any significant difference between the luting media on mid mesial axial surface.

Group	N	Mean	Standard Deviation	Median	Min	Max	Chi Value	p Value
AZ	12	46.77	12.74	49.88	27.38	61.34	10.299	**.006**
AG	12	29.86	19.09	20.77	10.69	63.69		
AR	12	60.35	25.40	55.98	33.50	107.76		

Table 6.8: *Comparing the mean marginal adaptation on mid-lingual axial surface between the groups*

Surface	Comparison	Z Value	p Value
Mid-lingual margin	Resin cement V/s Glass ionomer cement	-2.887	**0.003**
	Resin cement V/s Zinc phosphate	- 1.328	0.198
	Glass ionomer cement V/s Zinc Phosphate	- 2.309	**0.020**

Table 6.8 (A): *Inter group comparison of Mean marginal adaptation*

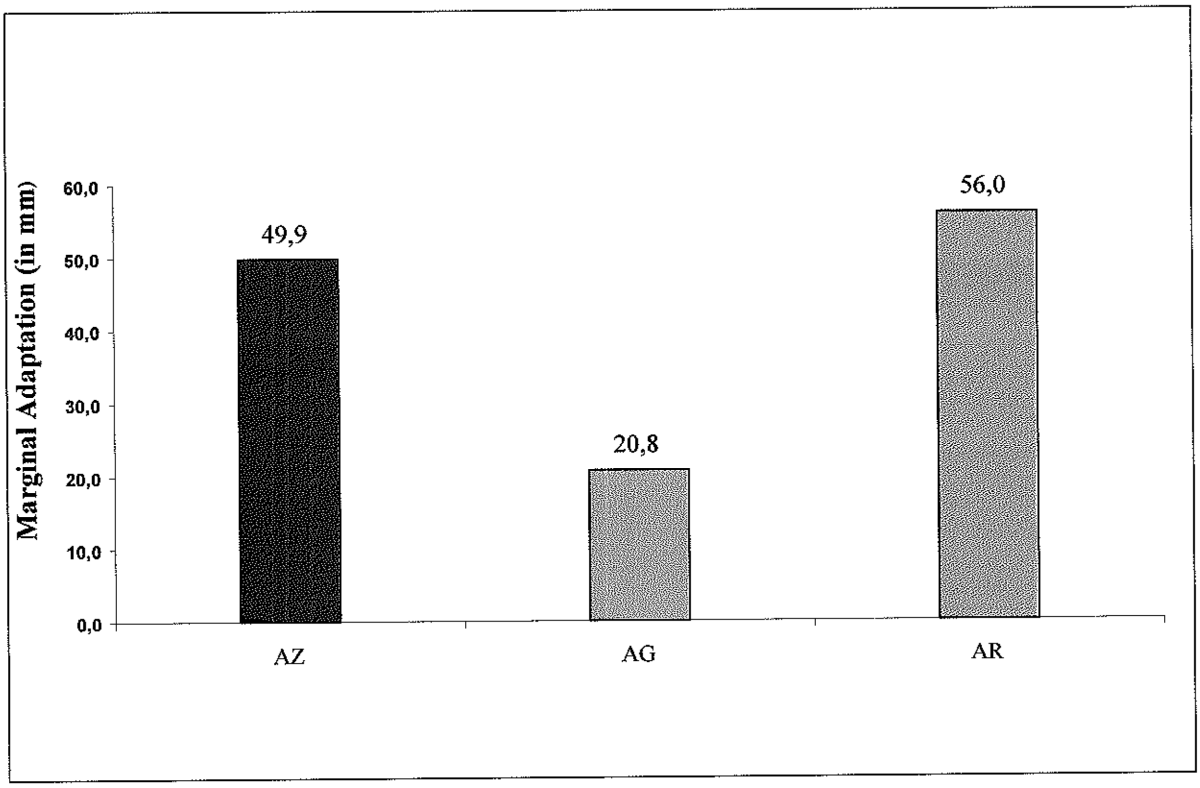


Table 6.8 (B): *Comparison of marginal adaptation on mid-lingual surface between incisors and molars and between groups.*

The comparison of the mean absolute marginal discrepancy of the individual study group on mid-lingual surface revealed significant difference ($p = 0.05$) among the study groups.

Specific luting media comparison on the mid-lingual surface showed that, resin cement V/s, glass ionomer cement and glass ionomer cement V/s zinc phosphate showed significantly wider marginal discrepancy compared to resin cement V/s glass ionomer cement

Group	N	Mean	Standard Deviation	Median	Min	Max	Chi Value	*P* Value
AZ	12	55.33	13.03	53.37	34.31	78.54	7.902	**.019**
AG	12	35.85	15.76	32.95	14.55	59.95		
AR	12	45.03	12.06	48.02	21.49	63.91		

Table. 6.9: *Comparing the mean marginal adaptation on mid-distal axial surface between the groups*

Surface	Comparison	Z Value	*P* Value
Mid-distal margin	Resin Cement V/s Glass ionomer cement	-1.559	0.128
	Resin cement V/s Zinc phosphate	-1.732	0.089
	Glass ionomer cement V/s Zinc phosphate	-2.540	**0.010**

Table. 6.9 (A): *Median marginal adaptation comparison among the inter group.*

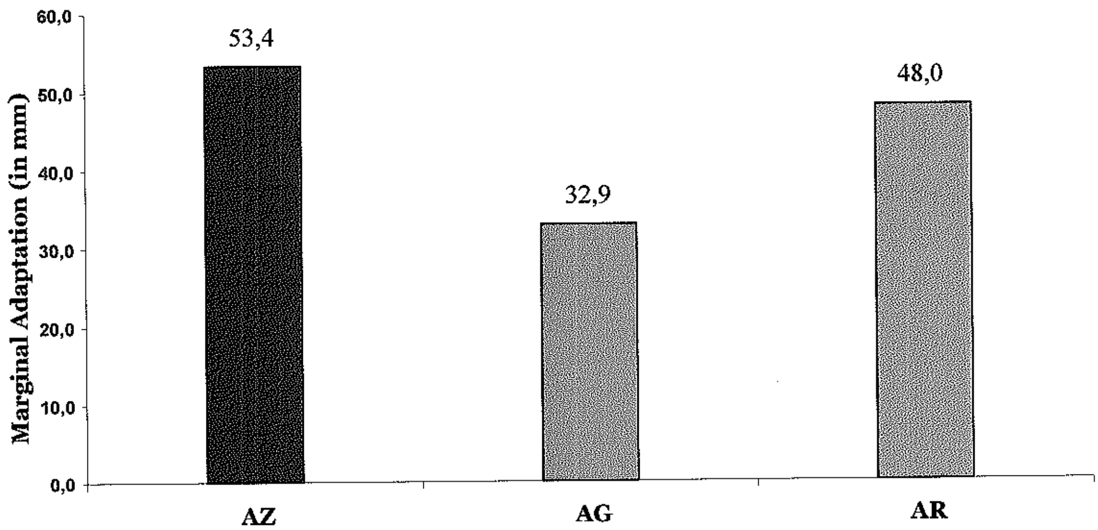


Table 6.9 (B): *Comparing the Median Marginal Adaptation on "mid-distal" axial surface between the Group*

The comparison of the mean absolute marginal discrepancy of the individual study group on mid-distal surface revealed significant difference ($p = 0.05$) among the study groups.

Specific luting media comparison on the mid-lingual surface did not show significance between resin cement V/s, glass ionomer cement and resin cement V/s zinc phosphate but glass ionomer cement V/s zinc phosphate showed significantly wider marginal discrepancy.

Group	N	Mean	Standard Deviation	Median	Min	Max	Chi Value	*P* Value
AZ	12	53.92	12.95	53.37	30.63	73.15	13.317	.001
AG	12	32.48	12.46	29.304	17.08	57.64		
AR	12	47.35	9.02	44.71	32.37	65.34		

Table 6.10: *Comparing the "median absolute marginal adaptation" between the groups*

Surface	Comparison	Z Value	*P* Value
Absolute marginal discrepancy	Resin cement V/s Glass ionomer cement	-2.887	**0.003**
	Resin cement V/s Zinc phosphate	-1.270	0.219
	Glass ionomer cement V/s Zinc phosphate	-3.175	**0.001**

Table. 6.10 (A): *Inter group comparison of Mean marginal adaptation*

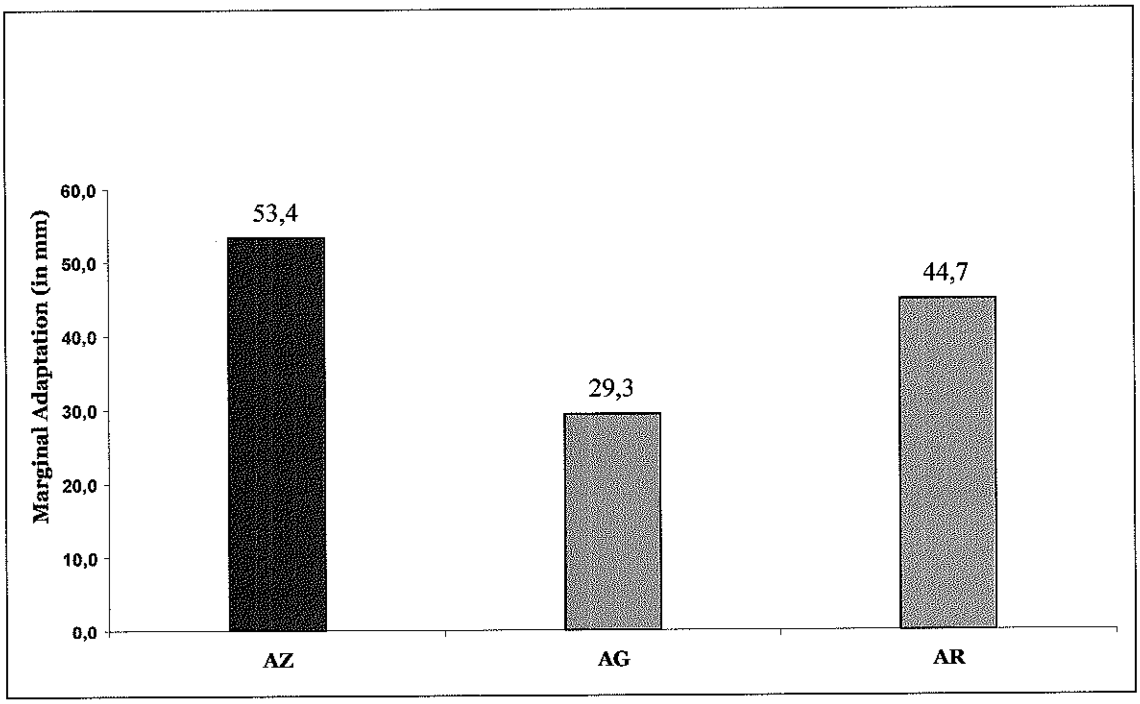


Table 6.10 (B): *Comparing the Median Marginal Adaptation between the groups*

Finally, the effect of luting media over median absolute marginal discrepancy of individual study group comparison showed significant difference.

Specific luting media effect over the median absolute marginal discrepancy showed significant difference between resin cement V/s glass ionomer cement and glass ionomer cement V/s zinc phosphate cement, except for resin cement V/s zinc phosphate.

The mean value of marginal adaptation of incisors and molars are presented separately in Table no V. Zinc phosphate cement [group AZ] incisors had 60 µm gap [s.d.: 13, min-max 42-30], while molars had a gap of 50 µm [s.d.: 11.7, min-max: 30-65], but they did not differ significantly with each other [$p = 0.240$]. With glass ionomer cement [group AG], incisors had 34.9 µm gap [s.d.: 13.5, min-max: 23-57] but molars 27 µm [s.d.: 9.4, min-max: 17-41] but they did not differ significantly from each other [$p = 0.240$] For dual cured resin cement [group AR] the incisors had 44 µm gap [s.d.: 7.1, min-max: 32-52] and molars 45 µm [s.d.: 10.8, min-max: 39-65] they did not differ significantly with each other [$p = 0.485$].

The affect of the axial surfaces over the marginal fit of the Procera® AllCeram copings was analysed. The mean marginal gap on "mid-buccal"surface of AG group was least [38.8 µm], while it was highest for the AZ group [61.1 µm]. There were significant differences [p =. 013] on the mid buccal surface among the three groups. On mid-mesial surface least value was for AG group [30.4 µm] and highest was for AZ group [41.6 µm], while there were significant differences [p = 0.100] between the groups. "Mid-lingual" surface AG group had least marginal gap [20.7 µm] and the highest was for AR group [56 µm] and found the significant differences [p = 0.006] between the groups. On "mid-distal" surface the least gap was with AG group [32.9 µm] and highest was for AZ group [53.4 µm], found statistically significance [p = 0.019] between the groups. Among all the surfaces, AG group showed the very least marginal gap value for incisors and molars.

Incisors showed highest marginal gap on "mid-buccal" [85.4 µm] and "mid-lingual" [60.8 µm] surfaces when compared to the mid-mesial and mid-distal surfaces. However, for the molars "mid-lingual" [59.8 µm] and "mid-distal" [57.3 µm] surface demonstrated the highest marginal gap value compared to mid-buccal and mid-mesial surfaces.

Primarily, the effect of three luting cement over the mean marginal adaptation of the four axial surfaces, independent of the tooth type were compared. On the "mid-buccal" surfaces there were significant differences between the groups AR to AZ [p = 0.007], AG and AZ [p = 0.014] but AR and AG group did not show any significance [p = 0.799]. On "mid- lingual" surfaces significance differences were shown between AR and AG [p =0.003], AG and AZ [p = 0.020] groups, but AR and AZ did not show any significance [p = .198]. On "mid-distal" surface there was significance between AR and AG group [p = 0.010] but between AR and AG [p = 0.128], and AR and AZ [p = 0.089] groups there was no significance. However, on the "mid-mesial" surface there was no significance between AR and AG [p = 0.114], AR and AZ [p = 0.755], and AG and AZ [p = 0.045] groups. Thus it was confirmed that, there was a significant effect of the type of luting agent used over the marginal fit of Procera® AllCeramic crown copings when compared to all the four axial surfaces.

Subsequently, the effects of luting cements over the "mean absolute marginal adaptation" of the tooth, independent of the tooth groups were compared. This analysis showed that, there is significant difference [$p = 0.001$] between the three luting cement groups over the mean marginal gap of the Procera® AllCeram copings. Specific inter group comparison revealed that there was significant difference between AR and AG [$p = 0.003$], AG and AZ [$p = 0.001$] group, but with one exception, AR and AZ group [$P = 0.219$]. This confirmed the overall effect of luting agents over the mean absolute marginal adaptation of Procera® AllCeram copings.

7
DISCUSSION

7. Discussion

7.1 Discussions of methods.

7.1.1 Use of Typodont teeth.

In this study Acrylic model teeth AG 3 [Frasaco, Germany] were used to simulate the clinical condition of all ceramic crown preparations. This eliminated the possible variation in standardisation of the samples on the basis of tooth size and form, before and after the tooth preparation. However, they eliminate the possible information imparted by the adhesion of the luting agents to natural dentin.

Few studies have been reported, which used the natural teeth to find the vertical marginal adaptation of the metal or all ceramic crowns [58, 65]. The difficulties of using the natural tooth as sample are standardization of the tooth size and form, variation in the individual structure, age and the storage time of the teeth after extraction.

Some studies strongly recommend the use of metal dies of the tooth preparations [72]. Their advantage is that they can be standardized with the same physical properties and dimensions. However, metal abutments give no information about the chemical and/or micro mechanical adaptation of luting materials.

7.1.2 Tooth preparation

For the CAD/CAM produced AllCeram crowns, tooth preparation plays the major role during the digitisation of the tooth preparation. Finish line design also determines the longevity of the crown restoration. The fabrication of CAD/CAM restorations demands a preparation with chamfer finish line and avoidance of near parallel surfaces, undercuts and sharp angles [21, 22, 25, 26]. All line angles needs to be rounded to reduce stress concentration in the final restorations. The recommendation to smoothen the final tooth preparation to 30 μm is advantageous while scanning the tooth details. However, smooth tooth preparation also appears to enhance the fit of final restorations [30]. Proos et al. [70] justified in their study the use of chamfer finish line in teeth with narrow mesio-distal and labio-lingual measurements.

Another study suggested that the use of 0.8 mm shoulder finish line with rounded internal angle, improved marginal fit and fracture resistance [94]. The same study stated that anatomical tooth preparation of the occlusal surface should not be prepared for CAD/CAM fabricated crown and bridge restoration. Another reason being that, the size of the Procera scanner tip prevents registration of this variation of the surface. Furthermore, the groove size of 2.5 mm wide and 0.5 mm depth could not be accurately reproduced with the Procera scanner tip [50].

7.1.3 Cementation of copings

Along with advanced multi step cementation using resin cement, the conventional cementation methods, are also being used for the cementation of Procera® AllCeramic crown. Zinc phosphate cement is the oldest luting agent and thus has the longest track record. It can serve as the standard by which newer luting systems can be compared [5]. This cement demonstrated high level of modulus of elasticity [13.5 Gpa] compared to the other conventional cementing agents. The intaglio surface of the Procera® AllCeramic crowns has an inherent micro roughness [3, 107] which can influence the mechanical interlocking of zinc phosphate cement. In a study by Barath et al. [8], it was demonstrated that zinc phosphate cement is beneficial in masking the black tooth discoloration.

Use of the Type 1 glass ionomer is justified because it has excellent biological advantages compared to resin cements along with the chemico-mechanical bonding capacity. Glass ionomer cement showed moderate translucency [8] with all-ceramic crowns, however final shade of the cement can be selected. Conventional luting medias, including glass ionomer cements, resin-modified glass-ionomer cements and composite resin luting agents can be used [74, 75] for cementation of the all-ceramic crowns. Study of microleakage from Albert et al. [2] determined that, Procera® AllCeramic crowns demonstrated moderate [49 %] microleakage with glass ionomer cement against other luting media.

Resin based composite cements are the material of choice for adhesive luting of all-ceramic crowns. Dual activated cements are popular alternative to the other resin based cements, because, it has long handling time, and the operator has a choice of selecting the shade of the cement. This type of cement is indicated for luting metal-based, or highly opaque, high strength ceramic crowns [48]. Even in the absence of light activation, the presence of chemical activator alone ensured a high degree of polymerization. Aesthetic benefits are also excellent along with minimal microleakage around the crown margins [2]

7.1.4 Use of scanning electron microscope for measurment.

The marginal accuracy of the crown is a clinical concern and decides long-term survival of the restorations. Holmes et al defined the seating discrepancy as 'lack of a seating of casting as it is measured perpendicular to the path of draw by arbitrary points on the external surface of the casting and the tooth away from the margin during measurement of marginal fit of the restorations [40]. The study from Groten et al. 1998 [34] reconfirmed that the circular marginal analysis is the most reliable parameter consideration to determine the marginal discrepancy of the given crown, and confirmed the accuracy of this methodology to as close as ±10 µm.

There are several methods available for the measurement of the marginal fit viz., direct viewing, sectioning, impression taking to make replicas, and explorative and visual examinations [58]. Important parameters such as consistency of measuring point and reproducibility of the methods used are critical for comparison of the data. In our study, direct viewing under scanning microscope, with coping fixed with respective luting agents, and 16 measuring spots were used. However, in 2000 Groten [33, 34] once again estimated the minimum number of measurements in direct viewing required in vitro for clinically relevant results, and found that a minimum number of 50 points randomly or systematically selected are needed. It was shown that, as the number of measuring points increased the accuracy of testing also increased.

We have used the direct viewing analysis using SEM, at four axial surfaces namely, mid buccal, mid-mesial, mid-lingual, and mid distal with a total of 16 readings per tooth. Although, earlier studies they used only 4 or 8 measuring points per sample. When we used the same methodology like the earlier studies we were able to eliminate the variation factor in methodology, and thereby compare our data results with their study results. However, we standardized the selection of the measuring spots among the samples by using the calibrated measuring tape; this also eliminated intra sample variations.

We also employed the die stone models of the tooth preparation to cement the coping. This is an accepted method for analyzing the accuracy of the fit in *in vitro* study, which has been used in several earlier studies [11, 58, 92, 103]. We measured only post cementation marginal discrepancy of crown copings in our study. This was evaluation of the marginal adaptation of the crown system after cementation and simulated very close to actual clinical condition of crown margin.

Although, besides SEM, earlier researchers have also used alternative methods to measure the marginal gap. They employed direct measurement, using digital microscope at magnification of 180X and 225X or stereomicroscope at 100X [65]. Different measuring methods may complicate the comparability of data. The use of the scanning electron microscope to measure the marginal gap was considered to be more accurate with sensitivity of 0.001 μm. The fit of the coping was measured without veneering because coping mainly determines the overall fit of the veneered crown and different stages of crown fabrication was proved to be not influencing the marginal fit of the Procera AllCeram crown [11, 58, 72, 90] Therefore the study mainly focused on the difference between the effect of tooth group and luting cement onto the marginal fit.

7.2 Discussion of the results.

7.2.1 Mean absolute marginal discrepancy of Procera® AllCeram copings

In this study the parameters used for the measurement of the marginal misfit was absolute marginal discrepancy. This is an angular combination of the marginal gap and an extension in the vertical and horizontal direction. According to the Holmes *et al.* [40] the consideration of measurement of absolute marginal discrepancy should be measured from the margin of the casting to the cavosurface angle of the chamfer preparation. Furthermore, the absolute marginal discrepancy would reflect the total and greatest misfit of the crown at the given spot, around the margin.

The reported mean absolute marginal discrepancy for incisor teeth of AZ, AG, and AR groups were (mean) 60, 38, 44 µm and for molars 49, 27, 50 µm respectively. We did not find significant difference between incisors and molars in same group. The values of incisors and molars of all the groups are within the clinically accepted marginal fit value of 100-120 µm. The values for molars are not in accordance with the study by Bindl et al., 17±16 µm [11]. In same study they used only molar teeth and the cement used was Panavia 21Tc (Kuraray, Dusseldorf, Germany). The numbers of predetermined measuring spot were 8 and were located around the margin. But Boening et al. [13] in his *in vivo* study reported that there were no significant differences in the mean marginal gap of anteriors, premolars, and molars. However, the posterior crowns had a tendency to have greater gap compared to the anterior teeth, which is not in accordance with our study result. The deviations in the reported value may be explained by different test methods used. However, there is no study which has been conducted in vitro, to compare the tooth group effect over the marginal fit of Procera® AllCeramic crown.

Further interpretation of the data revealed that absolute marginal discrepancy value of incisors of all the respective groups was lower than that of the molars, except for the AG group. This could be explained by the presence of larger surface area of the molars compared to the incisors, against the static finger load of 50 N during cementation procedure.

Incisors showed highest marginal gap on "mid-buccal" [85.4 μm] and "mid-lingual" [60.8μm] surfaces when compared to the mid-mesial and mid-distal surfaces. However, for the molars "mid-lingual" [59.8 μm] and "mid-distal"[57.3 μm] surfaces had the highest marginal gap value when compared to mid-buccal and mid-mesial surfaces. The results of present study are in accordance with the study results of Sulaiman et al. [90]. In his study maxillary incisor die stone models were used and he found that, incisors had 83 ±41μm of marginal gap. However, in the same study he showed that lingual and buccal side had wider gap compared to the other two axial surfaces.

A clinical study result of Kokubo et al. [46] of marginal fit also proved that there were no differences in mean marginal gaps among the anterior, premolar and molar tooth groups and values were 36,32, 35 μm respectively. Similar study by Suarez et al. [89] also did not demonstrate any difference in the marginal fit values from buccal to lingual axial surface margins. Deviations in the reported value may be explained by different test methods and type used in our study. One of the research hypotheses for our study was, that the tooth groups influenced mean absolute marginal discrepancy, but it was not supported by the study results.

The reported measurement of the absolute marginal adaptation resulted in an asymmetric distribution of the data. This could have been due to small size of sample (n = 6) used to compare the effect of incisors and molars over the absolute marginal adaptation. Earlier study results conducted to determine the absolute marginal discrepancy of Procera® AllCeram copings shows lot of variation. All the data has to be compared mainly under the preview of the study design. Variation in the methodology used also complicates the comparison of the data. According to the Beschnidt et al. [10], the evaluation of the marginal discrepancy depends on multiple factors. The factors are as follows:

- Measurements of cemented or not-cemented crowns.
- Storage time and treatment [e.g: aging procedures]
- Type of abutments used for measurements.
- Kind of microscope and enlargement factor used for measurements
- Location and quantity of single measurements.

Due to the limitations of the SEM imaging, only measurements of absolute marginal discrepancy in vertical dimension could be made. This evaluation did not account for any horizontal marginal discrepancies. However, the evaluation of vertical discrepancies was selected due to potential clinical significance, and this type of defects at the margins after cementation will expose the luting media to oral fluids. In contrast, horizontal discrepancies at margins can cause the step type of defect between crown and tooth interface [40]. This might interfere with cleanability and additional plaque retention. In addition to this we also did not consider investigating the internal fit of the crowns, however, this investigation require cross sectioning the crown copings, which would limit the marginal gap measurement to only limited number of sites.

Results of the *in vitro* studies should be viewed with caution, because in laboratory testing we cannot exactly simulate the clinical condition. The factors that can influence the marginal adaptation like, gingival retraction, variation of the margin preparation, and technique of the impression making couldn't be reproduced in this study.

7.2.2 Influence of the luting media over the marginal fit.

During crown cementation procedure there is complete filling of the cement space, which is provided during the designing stage of CAD/CAM crowns or bridges. The cementation should bring about minimum marginal discrepancy, and elevation of the crown in occlusal direction. To achieve this, the excess cement has to be expressed out by seating force. Different amount of the seating force, and methods have been recommended for seating the crowns and bridges [101, 105]

The conventional cementation technique is an accepted method of cementation for all-ceramic crowns and bridges. The primary adhesive mechanisms of the luting agents are through mechanical interlocking or chemico-mechanical bonding to the prepared tooth structure. The zinc phosphate cement is a luting agent, which adheres to tooth structures by mechanical interlocking to surface irregularities of tooth and the casting [5, 81]. Glass ionomer cement adapt to the tooth structure by chemico-mechanical bonding. The dual cured resin cement can adhere chemically and mechanically to the tooth and the all-ceramic coping structures. It also has the advantage of curing through self-curing capacity in inaccessible areas of the crowns [79]. The fitting surface of the Procera®AllCeramic crown has microroughness which is created during pressing and sintering, and this can influence the mechanical interlocking with luting media [107].

In the present study, effect of luting cements over the "median absolute marginal adaptation" of the Procera® AllCeram copings, independent of the tooth type were compared. This analysis showed that, there is significant difference [p = **0.001**] between the three luting cement groups over the mean marginal gap of the Procera® AllCeram copings. When the specific cement groups were compared, it revealed that there were significant differences between AR and AG [p = **0.003**], AG and AZ [p = **0.001**] group, with one exception, AR and AZ group [p = **0.219**]. This confirmed the overall effect of luting agents over the mean absolute marginal adaptation of Procera® AllCeram copings.

The median absolute marginal discrepancies values of our study [n = 12] were depicted in the **reducing order,** zinc phosphate cement [53 µm], resin cement [44 µm] and glass ionomer cement [29 µm]. We compared our results with the study result of Quintas AF et al. [70], who documented that there was no significant_effect of the luting cement over the vertical marginal discrepancies of Procera® AllCeram copings. In the same study, he presented the vertical marginal discrepancy after cementation in the

reducing order i.e., glass ionomer cement [46 μm], resin cement [45 μm] and least was zinc phosphate cement [41 μm].

Naert et al [58] in his study found that, marginal fit was not affected by the luting media, but concluded that marginal gap increased after the cementation of the coping. He also added that elevation of crown after cementation always exists in clinical situation. Beschnidt SM et al. [10], in his study, compared the marginal adaptation of five different types of all-ceramic crowns and concluded that, cementation increased the marginal discrepancy, and also found that there was no effect of conventional cementation and adhesive cementation over the marginal discrepancy.

In the present study, the type of the cementation force used was static finger pressure of 50 N/cm with standardization. This procedure was comparable to the clinical situation. However, the static force may not have been powerful enough when compared to dynamic force [79] and ultrasonic handpiece to transform the highly viscous luting agents into low viscosity under the present experimental condition. This could have prevented the complete marginal adaptation of the zinc phosphate and resin cement group copings.

It has been proved by study of CAD/CAM produced all-ceramic partial crowns that, high viscosity luting agents resulted in larger marginal interfacial widths than the low viscosity luting agents [53]. But the condition, in which the present experiment was conducted, was not close to the clinical condition, in simulating the direct bonding of the resin cement to the tooth structure, because we used the die stone models instead of natural tooth, which would have influenced the final interpretation of experimental value of the AR group.

In the present study, zinc phosphate cement [AZ] group demonstrated the highest median absolute marginal discrepancy of 53 μm in comparison to other groups. Study result of intracoronal pressure during cementation of crown demonstrated that, zinc phosphate cement produced the greatest peak of hydrostatic pressure in the centre of the occlusal surface [39] during cementation procedure. This was further supported by the study of

Wilson [101, 104], who suggested the venting of the crowns in order to relieve the stress concentration of casted crowns. This could be partially responsible for the wider absolute marginal discrepancy of AZ group. Yu et al. [105] also asserted that there is definitive interaction between the type of cement used and cementation technique over the final seating of the crown. While this investigation was not a comparison of the cementation technique there was a fundamental focus to measure the marginal gap of Procera® AllCeram crown copings.

We also need to consider the relationship of marginal opening and marginal leakage of crowns. The study result confirmed that, there is no significant correlation between marginal opening and microleakage of cast crowns [36, 99, 68]. But a similar study with all-ceramic crowns was showed that the luting agents did not influence marginal adaptation. Furthermore, it proved that the group cemented with zinc phosphate had the highest amount of microleakage but the least was with adhesive composite resins. Similar study with Procera® AllCeram crowns found significant association between cement type and microleakage [2]. The microleakage value of study are documented in reducing order, zinc phosphate 76 %, glass ionomer 49 % resin modified glass ionomer 10 % and resin cement 34 %. But mean value of marginal adaptation of all the cements used in his study was 54 μm while in our study value was 42 μm.

Further research should focus on an increased number of specimens when evaluating the effect of tooth group over the marginal adaptation, and use different luting cements with natural teeth sample to understand the effect of chemical bonding effect of resin cements. Furthermore, measure the internal gap of the samples with the same methodology would disclose the total quantification of the 'misfit' of Procera®AllCeramic copings.

7.2.3 Cement space and its effect over the marginal discrepancy

For metalo-ceramic restoration, it was earlier suggested and later proved that die spacing is essential in improving the complete seating of the cast crowns [23, 64,]. The function of the die spacing is to provide the space for the cementing media, thereby reducing the stress concentration during cementation of crowns. This can also result in achieving better fit of the final restoration by providing the space for excess cementing media to flow during cementation.

In 1993, Grajower et al. [32] affirmed that '**an optimum fit of the casting can be obtained only if the relief space allows for the cement film thickness and roughness of tooth and casting surface**'. He further recommended the application of the die spacer of 50 µm thickness starting from 0.5 mm short of external finish line, [30 µm for cementing media, and 20 µm for distortion of wax]. In a study by Olivera et al. [62] with cast crowns, it was found that when the 25 µm cement spacing was set 0.5 mm short of marginal finish line, the marginal adaptation was good with glass ionomer cement followed by zinc phosphate and resin cement. But the resin cement provided the highest retentive strength.

In Procera System, the cement space provided is 50 µm thickness. This space is uniform and extends till 1mm short of cavosurface margin of finish line [58]. This space is a predetermined setting by the manufacturer and can be incorporated during the designing stage of the coping.

When we reviewed the studies in this regard, we found that luting space setting did affect the marginal fit of the CAD/CAM produced Cerec 3 fabricated crowns [7, 83]. Another interesting observation was that, as the amount of cement space setting increased the marginal gap reduced. Another study of marginal fit and internal adaptation of the Procera® AllCeramc copings found that the large internal gap [occlusal] width favoured the small marginal gap dimension [11, 46]. Studies by the Quintas et al. [72] postulated that since the cement space was greater in AllCeramic coping, the luting agents might have flowed more quickly during cementation procedure. This might have reduced the marginal gap with Procera AllCeramic copings compared with other all-ceramic systems.

The cement space provided in our study was 50 µm. Therefore in comparing the results of our investigation with other investigations, evidence suggests that the mean absolute marginal adaptation of the Procera® AllCeramc crown coping is within biologically acceptable measurement, which is 100 µm with all luting a media.

7.2.4. Geometry of tooth preparation and its effect over the marginal discrepancy

Most fixed prosthesis depends on the geometry of the tooth preparation for their retention. The cement is very effective in retaining the crown, provided the crown has only single path of removal. Theoretically, maximum retention is obtained if the tooth preparation has parallel walls [80]. Slight convergences of the walls are necessary, but this taper should only provide limited path of withdrawal. Jorgensen et al. [42] demonstrated the relationship of degree of axial wall taper and magnitude of the retention and they suggested that 6 degrees of axial wall taper is ideal to achieve good retention.

In this direction numerous studies have found a positive relationship between the convergence angle of the tooth preparation and marginal adaptations of the crown. But study results do not have consensus with regards to factors affecting the marginal discrepancy of the crown. Study from Chan et al. [14] demonstrated the positive relationship between the convergence angle and seating discrepancies of complete crown restorations. Another investigation compared the effect of occlusal convergence angle of the abutment and luting space setting of marginal fit of Cerec 3 crowns. The results of the investigation suggested the negative relationship between occlusal convergence angle and marginal adaptation [59]. In our study we had incorporated 6 degrees of axial wall taper for the crown preparation.

In fixed partial denture gingival finish line configuration plays an important role in the marginal adaptation. The studies in this direction with ceramo-metal restoration do not comply that there exists a definitive correlation between designs of the finish line and the overall marginal fit of restoration [9, 91]. With CAD/CAM produced

Procera®AllCeramic restoration, the design and the dimension of the finish line is important during digitisation of the tooth preparation [50]. The investigation of different all ceramic materials, did not find any influence of the type of margin design influencing the marginal adaptation of Procera coping before and after the cementation [72].

8

CONCLUSIONS

CONCLUSIONS

Within the limitation of this in vitro experiment, the following conclusions were drawn:

1. Scanning electron microscope [SEM] measurement of mean absolute marginal discrepancy of Procera AllCeram copings [$n = 6$] were as follows: –
   - AGI- 37.9 µm, AGM- 27 µm. ARI- 44 µm, ARM- 50 µm, AZI - 59 µm, AZM- 48 µm.
   - All the absolute marginal adaptation gap size was within the biologically acceptable standards of all-ceramic restorations.
   - Incisors showed wider marginal gap on mid-buccal and mid-lingual surface, but for molars there was wider marginal gap on mid-lingual and mid-distal surfaces.
   - Incisors showed the wide absolute marginal gap than the molars in the entire group.

2. There was no statistically significant difference ($p<0.05$), in absolute marginal discrepancy of incisor and the molar tooth Procera® AllCeram copings as a **function of tooth group variation.**

3. There was statistically significant difference ($p<0.05$) in median absolute marginal adaptation of Procera® AllCeram copings as a **function of effect of luting media** ($n = 12$).

   - AZ group-53 µm; AR group– 44.5 µm; AG group-29 µm.

   - The **AR** group showed the significantly smaller ($p<0.05$) and homogeneous absolute marginal gap than the **AZ** group. The **AR** group presented significantly larger ($p<0.05$) and variable marginal gap dimension compared with AG group. There was no significant difference in absolute marginal discrepancy between **AR** group and **AZ** group at the $P = 0.05$ level.

- Glass ionomer cement group demonstrated the least absolute marginal discrepancy in this study, compared to zinc phosphate cement and resin cement.

9

CLINICAL IMPLICATIONS

CLINICAL IMPLICATIONS OF THE STUDY

1. This in vitro study demonstrated that the marginal discrepancies of Procera®AllCeram alumina copings tested were within the biologically acceptable standard of 100 μm.

2. The Procera® AllCeramic crown can be prescribed in anterior and posterior teeth with confidence.

3. Uniform chamfer design of gingival preparation of a crown with 30 μm final finishing, with an acceptable method of impression is also very critical for the good clinical crown fit.

4. When a clinical situation dictates the sub gingival crown margin placement, the glass ionomer cement under static finger pressure could be recommended as luting media.

5. If the zinc phosphate cement is selected as the luting media, then limited cement coating onto the fitting surface with dynamic crown placement or ultrasound technique within 20 seconds of initial crown placement would be ideal.

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11
SUMMARY

SUMMARY

In recent years introduction of high strength oxide based all-ceramic system made metal free ceramic restorations a popular aesthetic alternative in anterior and posterior region of the mouth. One of the materials is the Procera® AllCeramic densely sintered alumna [Nobel Biocare AB, Goteborg, Sweden]. The quality of restorative material such as strength, biocompatibility, aesthetics and fit have been studied and documented in great detail. Long-term survival qualities of the materials are partially related to the marginal adaptation of the crown to the margins of the crown preparations. *In vitro* studies need to confirm such quality of the Procera® AllCeram crown coping.

Aims of the studies:

The main aim of the thesis was to investigate the mean absolute marginal discrepancy of Procera® AllCeramic [densely sintered alumna] crown copings. The second aim of the study was to investigate the whether marginal fit of Procera® AllCeram copings can be influenced by the tooth groups [incisors, molars]. The additional aim was to investigate the marginal gap value differences depending upon their location within the tooth. The final aim of the study was to investigate whether the cementing media can influence the marginal adaptation of the Procera® AllCeram crown copings.

Materials and methods:

Two incisors and two molars typodont teeth were prepared for all-ceramic crown according to manufacturers instructions with 0.8 mm of chamfer finish line. These four individual teeth were duplicated nine times [9] to obtain total 36 die models and devided in to three group of 12 teeth.. Procera® AllCeramic 0.6 mm coping were fixed, first group [AZ] using zinc phosphate cement [Adhesor®] n = 12, second group with glass ionomer cement [Kavitan® Cem] n = 12, and third group dual cured cement [Dual® Cement] n = 12. Marginal adaptation was measured using direct scanning electron microscopy [SEM] on all four axial walls with 4 measurements on each wall with total of 16 measurements per tooth. The influence of between coping factors [luting cement] and within-coping factor [tooth group and axial surface] on the marginal adaptation of the Procera® AllCeram crown copings were assessed.

Results:

The mean absolute marginal adaptation value of groups are AG I [n = 6] 37.9 μm, AG M [n = 6] 27 μm. AR I [n = 6] 44 μm, AR M [n = 6] 50 μm, AZ I [n = 6] 59 μm, AZ M [n = 6] 48 μm. There was no statistically significant difference in mean absolute marginal discrepancy between tooth groups. Within the axial surface marginal adaptation gaps comparison revealed that incisors had wide gap on mid-buccal surface [85.4 μm ± 31.5] and mid-lingual [60.8μm ±36], but molars had mid-lingual [59.8 μm ±10] and mid-distal [57.3 μm ± 13] respectively. The median absolute marginal gaps of study groups were compared for significance. AG group had low mean gap [32.5 μm ±12] and high gap was with AZ group [53 μm ±12]. There were significant difference between the luting agent, AR V/s AG and AG V/s AZ except AR V/s AG group.

Conclusions:

Absolute marginal discrepancy measurement of Procera® AllCeram copings of incisors and molars demonstrated the biologically acceptable marginal adaptations value of 100 μm. While tooth group variations [incisors and molars] did not affect the adaptations of Procera® AllCeram copings. Buccal and lingual axial surface of incisors and distal and lingual surface of molars showed the wide marginal gap. Considering the individual factors separately, luting agents appeared to be affecting the mean marginal adaptation. The absolute marginal discrepancies were recorded in ascending order, AZ group - 53 μm; AR group – 44.5 μm; AG group - 29 μm.

SOUHRN

Vývoj celokeramických systémů založených na oxidu hlinitém a oxidu zirkoničitém způsobil, že se bezkovové celokeramické korunky a můstky staly žádanou alternativou při ošetřování zubů ve frontálním i laterálním úseku chrupu. Jedním z těchto materiálů je systém PROCERA založený na sintrovaném oxidu hlinitém (Nobel Biocare, Goteborg, Sweden). Bylo provedeno mnoho studií týkajících se vlastnosti tohoto materiálu, jako je pevnost, biokompatibilita, estetika a přesný okrajový uzávěr, což je přesná adaptace cervikálního okraje korunky ke schůdku, kterým je preparace v oblasti krčku zubu ukončena. Tyto faktory ovlivňují dlouhou životnost náhrad v dutině ústní. Právě kvalitu okrajového uzávěru mohou potvrdit *in vitro* prováděné studie.

Cíle studie:

Prvním cílem studie bylo zjistit průměrnou absolutní přesnost okrajového uzávěru bazálních kapen zhotovených z materiálu PROCERA AllCeram (denzně sintrovaný oxid hlinitý).

Druhým cílem studie bylo zjistit, zda vertikální přesnost okrajového uzávěru bazálních PROCERA AllCeram kapen může být ovlivněna skupinou zubů (řezáky, moláry).

Třetím cílem studie bylo zjistit, zda rozdíly ve velikosti marginální spáry v oblasti okrajového uzávěru závisí na jejich lokalizaci v rámci jednoho zkoumaného zubu.

Čtvrtým cílem studie bylo zjistit, zda typ cementu použitý k fixaci kapny na zub může ovlivnit „průměrnou absolutní přesnost okrajového uzávěru" PROCERA AllCeram kapen.

Materiál a metody:

Vyšetřované zuby – 2 plastové střední horní řezáky a 2 plastové první horní moláry- byly podle instrukcí výrobce kapen preparovány na celokeramickou korunku s ukončením preparace v cervikální oblasti na oblý schůdek šíře 0,8 mm. Tyto 4 zuby byly 9krát duplikovány za účelem získání souboru 36 sádrových replik. Bylo vyrobeno 36 PROCERA AllCeram kapen tloušťky 0,6 mm. Tento soubor byl rozdělen na 3 podskupiny; 12 kapen 1. podskupiny označené AZ bylo fixováno zinkoxidfosfátovým

cementem Adhesor. 12 kapen 2. podskupiny označené AG bylo fixováno glasionomerním cementem Kavitan Cem a 12 kapen 3. podskupiny označené AR bylo nacementováno duálně tuhnoucím cementem Dual Cem. Přesnost marginální adaptace byla změřena pomocí přímého skenování rastrovacím mikroskopem (SEM). Proběhla 4 měření na každé ze 4 axiálních stěn (vestibulární, orální, mesiální a distální) každého zubu. Tímto způsobem bylo získáno 16 měření pro každý zub ze souboru. Hodnocen byl vliv určitých faktorů na přesnost marginální adaptace PROCERA AllCeram kapen. Těmito faktory byly jednak rozdílné typy zubů a fixačních cementů, jednak měření na jednom každém zubu z celého souboru (4 měření na 4 axiálních stěnách).

Výsledky:

Hodnota průměrné marginální adaptace souborů je u podskupin AGI (n = 6) 37,9 μm, AGM (n = 6) 27 μm. U podskupin ARI (n = 6) 44 μm, ARM (n = 6) 50 μm, AZI (n = 6) 59 μm, AZM (n = 6) 48 μm. Nebyl zjištěn statisticky významný rozdíl průměrné vertikální marginální adaptace mezi jednotlivými podskupinami zubů a všechny hodnoty průměrné marginální adaptace splňují přijatelný limit 100 μm. Kruskalův-Wallisův test však ukázal statisticky významný rozdíl mezi typy zubů v adaptaci kapen k axiálním stěnám zubů ($p<0,05$). Ukázalo se, že řezáky mají širší spáru ve středu labiálního povrchu zubu (85,4 μm ± 31,5 μm) a ve středu palatinálního povrchu zubu (60,8 μm ± 36,0 μm), kdežto moláry vykazovaly širší spáru ve středu palatinálního povrchu zubu (59,8 μm ± 10,0 μm) a ve středu distálního povrchu zubu (57,3 μm ± 13,0 μm). Průměrné marginální spáry u zubů jednotlivých podskupin byly navzájem statisticky vyhodnoceny. AG podskupina vykazovala úzké spáry (32,5 μm ± 12 μm), naopak široké spáry se objevovaly u podskupiny AZ (53,0 μm ± 12,0 μm). Byl objeven signifikantní rozdíl mezi typem cementu, který byl použit k fixaci kapny na zub, AR V/s, AG a AG V/s s výjimkou podskupiny AR V/s AG.

Závěr:

Studie potvrdila, že diskrepance mezi absolutními hodnotami marginálních spár naměřených u PROCERA AllCeram kapen fixovaných na řezácích a molárech poskytují kapnám, resp. korunkám, akceptovatelný okrajový uzávěr (100 μm). Variace v rámci podskupin (řezáky, moláry) neovlivnily adaptace PROCERA AllCeram kapen. Labiálně a palatinálně u řezáků a distálně a palatinálně u molárů vykazoval okrajový uzávěr kapen široké spáry. Uvážíme-li individuální faktory, zdá se, že zvláště fixační cementy, ovlivňují průměrnou marginální adaptaci použitých kapen. Absolutní marginální spáry byly zaznamenány (v sestupné řadě): AZ skupina – 53,0 μm, AR skupina – 44,5 μm a AG skupina – 29,0 μm.

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