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Marginal Adaptation - A Review

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ABSTRACT: Fixed dental restorations mainly aim to restore function and esthetics of lost intra oral structures without jeopardizing the oral or general health of the patients. Marginal discrepancy can be defined as the vertical distance from the finish line of the preparation to the cervical margin of the restoration. Although terminology describing "fit" and the technique used to measure fit may vary considerably in literature. In this work, the measurements of "fit" at different locations are geometrically related to each other and defined as internal gap, marginal gap, seating discrepancy etc.

Keywords:-Marginal fit, misfit, seating discrepancy.

INTRODUCTION

The main goal of a fixed restoration is the close adaptation of the crown to the prepared tooth. Achieving aesthetically and functionally restorations has been the goal of dental clinicians, prosthodontists and manufactures throughout history of dentistry[1]. The success of a dental restoration is determined by three factors: esthetics value, resistance to fracture, and marginal adaptation. Inadequate fit leads to plaque accumulation, which increases the risk of carious lesions, and can cause microleakage and endodontic inflammation.

Holmes et al, proposed a clear terminology for marginal fit in 1989. Marginal fit is generally evaluated by measuring the marginal gap or the absolute marginal discrepancy[1].

Historically, high noble cast restorations have shown smaller marginal discrepancies than base metal alloy, metal ceramic or ceramic restorations. Some studies have reported marginal gaps smaller than 10 µm for high-palladium-content alloys and for gold platinum-palladium alloys, whereas other studies have found marginal discrepancies between 18 and 46 µm. Marginal openings from 50 to 120 µm are considered clinically acceptable in terms of longevity[2].

The misfit measurements at various points between the cast surface and the tooth are the best definition of the marginal fit. This misfit includes the internal gap, marginal discrepancy, and vertical marginal discrepancy and horizontal marginal discrepancy, overextended margin, absolute marginal discrepancy, and seating discrepancy[3](Fig. 1).

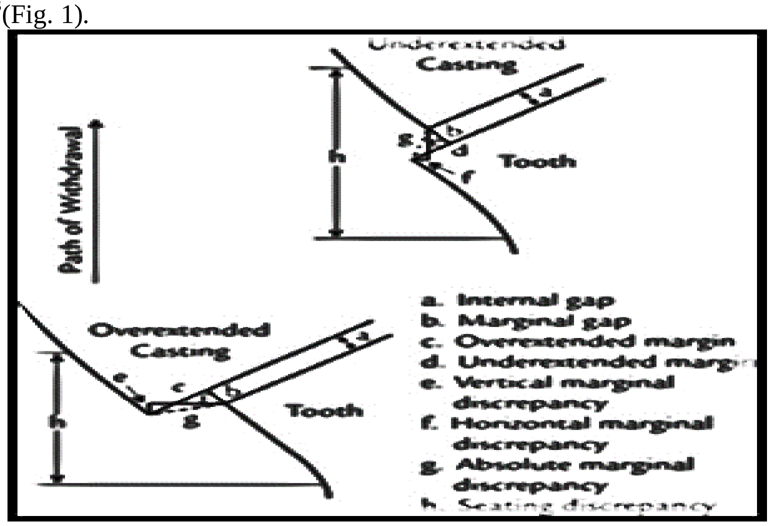

Fig. 1: Casting misfit terminology.

There are various steps involved in the fabrication of crown and the fit of the crown is dependent on various steps involved which are as follows:

1. Preparation of the tooth (Margin Line)
2. Gingival displacement
3. Impression technique
4. Die spacer design
5. Wax pattern
6. Casting
7. CAD-CAM
8. Laser Sintering
9. Cementation

I. PREPARATION (FINISH LINE):

Metal ceramic and all- ceramic crowns are used frequently to restore esthetics and function. Restorations with poor marginal integrity may contribute to the cause of severe caries and periodontal defects[4]. The most important factor in achieving successful marginal integrity is preparation design, Inadequate tooth preparation can also lead to esthetic failure.

Criteria for Margin Selection:

While adequate tooth reduction is necessary to provide sufficient space for the metal and ceramic to satisfy both esthetic and mechanical requirements, such a reduction should be accomplished without endangering the pulp or supporting periodontal structures. Therefore, ideal finish line should allow for optimum thickness of both metal and porcelain to satisfy the mechanical and aesthetic requirements.

1. The selected margin must provide a predictable level of marginal integrity.
2. To minimize plaque accumulation, the selected margin must present smooth materials to the gingival sulcus.
3. The margin also must provide acceptable esthetics[5-7].

With metal-ceramic crowns the potential cervical margins to considered are- Knife-edge, flat shoulder (butt-joint), 135◦ shoulder (long bevel, sloped shoulder), flat shoulder with 45◦ bevel (bevelled shoulder), flat shoulder with 70◦ bevel, chamfer, and deep chamfer with bevel[8].

There are three cervical margin designs that seem to meet the criterion related to acceptable marginal integrity. These include the shoulder, the shoulder-bevel and deep chamfer.A 90- degree shoulder is probably the most commonly used margin designs for porcelain fused to metal (PFM) restorations[9,10]. The shoulder and shoulder-bevel margin seem to resist distortion due to the inherent bulk of metal at the margin. The shoulder can be used with a metal margin, which can be highly polished, or with a porcelain margin, which results in glazed porcelain in the sulcus.These designs require the removal of a significant amount of tooth structure to provide a predictable restoration. This increases the risk of irreversible damage to the pulp, particularly if little tooth structure is present, for example on exposed roots[11,12]. In these situations more conservative designs is considered.

Chamfer margin has been defined based on their marginal width and/or geometry. Jacobsen and Robinson stated that a width greater than 0.3mm at its cervical termination precluded any margin being called chamfer.

The favoured thin marginal design for metal free crownssuch as the lithium disilicate crown (E-max)that there is a tendency to “underprepare” teeth. The consequences of under preparation is usually worse than those associated with preparations that are wider than the absolute minimum required by the restorative material[13].

Thin finish lines have been advocated in the belief that they allow marginal closure through intraoral finishing and contribute to the maintenance of pulp vitality.

However, review of literature indicates that the efficacy of the intraoral finishing procedures should be reassessed. The ability of the dental technician to produce anatomic crown contours while working to the minimum possible thickness of material has been overestimated. If maintaining a normal emergence profile is important, then wider margins allow easier fabrication of appropriately contoured crowns while also improving rigidity and esthetics.

The influence of the marginal design of a full crown on the occlusal seat andmarginal seal of a cemented full crown restoration was examined. Under theconditions of the study, the featheredge and parallel

bevel preparationsdemonstrated the best marginal seal, followed in order by the full shoulder,45° shoulder, and finally the 90° shoulders with 30° and 45° bevels[14].
Previous comparison studies have shown that the marginal adaptation of the all-porcelain labial margin in metal ceramic restoration is very technique sensitive[15].

II. GINGIVAL DISPLACEMENT

Glossary of prosthodontic terms -8 describes gingival displacement as the deflection of the marginal gingiva away from the tooth. Its goal is to reversibly displace the gingival tissue[16].

Gingival displacement helps to provide an accurate margin fit and axial contour of the restoration, thereby, preventing recurrent caries and plaque accumulation. Also, helps in recording the contour beyond the finish line to correctly contour the restoration and smoothly blend the margins of the restoration with the unprepared tooth surface[17].
Techniques such as mechanical, chemical, chemico-mechanical and surgical methods have been followed conventionally for gingival retraction. Soft tissue lasers can be used as a substitute to conventional retraction techniques, because they provide adequate retraction along with haemostasis, with less working time and good patient comfort.

A definite alternative for gingival retraction now exists in the form of retraction paste (Expasyl / Magic Foam Cord). In regard tohaemostasis, there is no doubt about the efficacy of these materials and their ability to be extremely effective clinically. The retraction procedure also appears very safe and easy to use. Thus, the newly advanced material in the form of retraction pastes like Expasyl or Magic Foam Cord have been found to be better than the cord, as assessed histologically, with respect to the periodontium. The patient tolerance was observed to be very good. No anaesthesiaisrequired, and the material exhibits a total biocompatibility[18].

III. IMPRESSION TECHNIQUE

Recent technological advancements have introduced alternatives to conventional impression methods through the use of computer-aided design and computer-aided manufacturing (CAD/CAM) and intraoral digital scanners.

These new technologies may offer similar or better results compared with conventional methods.For intraoral scanning devices to be considered an acceptable alternative to conventional impressions methods, they should yield crowns with similar or better clinical success.

To minimize process errors deriving from impression taking and model fabrication, it is only logical to transfer the scanning process to the patient and directly scan the preparations in the patient’s mouth. This approach was first realized by the CEREC system which is already commercially available for more than 25 years; since then, it has been continuously improved.

Meanwhile, the hardware is available in the fourth generation (CEREC Blue cam). However, this system mainly focuses on the chairside production of inlays and partial crowns[19].

In dental literature, there are many data available with regard to the CEREC system. However, little information could be identified regarding the E4D system. Overall, CEREC delivers acceptable results but the precision achieved does not outperform conventional impression techniques. On the contrary, recently introduced digital impression systems such as the Lava C.O.S. (3M ESPE, MN, USA), the iTerosystem (Cadent, NJ, USA), and the TRIOS digital impression device (3Shape, Denmark) are more focused on general reproduction purposes of the teeth. Subsequently, the indication for aforementioned devices has been broadened by their respective manufacturers. The marginal accuracy of a restoration is considered an important prerequisite for healthy periodontal conditions, whereas the internal fit is regarded relevant for the longevity of a ceramic restoration.

IV. DIE SPACER DESIGN

The incomplete fit of full cast crown restorations remains a critical problem for dentists, leading many researchers to study this problem. In the past, researchers believed that better retention would be achieved with a frictional fit between the coping and the tooth surface. This meant that during the cementation process, a perfect fit could not be obtained because of the lack of space for the luting agent. Die spacers allow increased space for the cement between the tooth surface and the internal surface of the casting, reducing stress areas created during cementation, and thereby resulting in better fit and retention of the final restoration. In fixed prosthetic treatment, luting agents have an important role in the final result. A luting agent that provides adequate marginal seal, without producing great vertical discrepancies in casting fit, makes an important contribution to a successful treatment result[20].

In 1993, Grajower and Lewinstein stated that “an optimum fit of the casting can be obtained only if relief space allows for the cement film thickness and roughness of the tooth and casting surfaces.’’ They affirm that applying a spacer on the die, including the base of the tapered region but excluding the horizontal part of the shoulder, is the most effective technique[21].

Also, they arbitrarily recommended a relief of 50 μm for the thickness of the spacer to be applied on the die surface. This value includes 30 μm for the cement film and surface roughness, as well as 20 μm for distortion of the wax pattern. In 1989, Grajower et al asserted that leaving part of axial walls uncovered with the spacer impaired the crown fit considerably. The average elevation of the latter was 653 μm when compared with 49 μm for the application of the spacer to the margin[22].

As per the study by Anna Belsuzarri Olivera in 2006, the best marginal adaptation of the uncemented castings was obtained when the die spacer covered all of the preparation down to 0.5 mm short of the marginal finish line. The castings cemented with ionomer-based luting agent provided the best margin adaptation when the die spacer covered all of the preparation down to 0.5 mm short of the marginal finish line[23].

V. FABRICATION OF A WAX PATTERN

The fabrication of wax pattern is a critical step in making of indirect restoration. Different techniques in wax pattern fabrication: 1. Dipping method. 2. Addition method. 3.Molten press method. 4. Injection method.Addition waxing is a conventional wax-adding technique by heating and melting the wax. Dipping waxing uses an immersion technique with a wax dipping unit at a high temperature. These techniques are also called lost wax techniques.

Becker et al. evaluated the marginal seal of crowns made from precious metals using manual waxing technique and concluded that precious metals showed favourable clinical results, thus preventing irritation to the periodontium, bacteria accumulation, and infiltration of the thermal conductivity to the dental organ[24]. Similarly, Christensen et al. evaluated the marginal seal of restorations with noble metals and concluded that an interface of 39 μm was clinically acceptable[25]. Foster et al. studied the most common cause of failure in the placement of crowns, finding that an interface of more than 120 μm caused periodontal complications[26]. Manual waxing and dipping waxing techniques require technicians to perform detailed craftsmanship. Accordingly, while manual waxing and dipping waxing techniques are used most frequently, several techniques for the preparation of fixed prostheses have developed to facilitate greater productivity and better quality.

Waxing instruments can be categorized by the intent of their design: 1. Wax addition, 2. Carving, or 3. Burnishing. Of the popular PKTs (designed by Dr. Peter K. Thomas specifically for the additive waxing technique), θ No. 1 and no. 2 are wax addition instruments, θ No. 3 is a burnisher for refining occlusal anatomy, θ Nos. 4 and 5 are wax carvers.Wax carvers. No. 2 Ward and nos./, and 3 Hollenback DPT no. 6 wax burnisher. Electric waxing instrument[27].

Wax pattern fabrication is a time-consuming task dependent upon the skills of the dental laboratory technician. Wax has several inherent limitations including delicacy, thermal sensitivity, elastic memory, and a high coefficient of thermal expansion. Wax manipulation results in a 0.4% shrinkage while casting can produce a thermal shrinkage of 0.2%[28].

In fabricating wax pattern, the die should be lubricated, preferably with a lubricant containing a wetting agent.

Any excess of the same should be avoided, because it would prevent the intimate adaptation to the die. When the margin are being carved, extreme care should be taken so as to not abrade any of the surface of the stone die[29].

Although wax is a convenient material, it also is easily distorted because of its tendency to flow, stress release, and expand or contract with the change in temperature. Even with the support of the die, the wax pattern may distort significantly if the ambient temperature changes or time(days) passes. However, when the wax pattern is removed from the die, distortion is a serious risk and may occur in only 1-2 mins. Thus, the shortest time possible elapse betweenthe pattern being removed from the die and the time it is invested. For this reason, the wax pattern is generally sprued while its on the die[30].

VI. CASTING

Casting is one of the most widely used method in the fabrication of dental restoration outside of the mouth, the ultimate assessment of cast restoration lies in the accuracy of fit of the castings and duplication of tooth morphology.

Taggart WH first introduced fabrication of a cast restoration by lost- wax technique in 1907. Casting fabricated with his method were undersize and couldn’t fit accurately. This was attributed to the alloy shrinkage[31].

As a result, Lane JG conceived the idea of casting into an enlarged mould, which he achieved using an investment containing a high percentage of silica (approximately 75%). He was thus first to introduce mould expansion as a shrinkage compensation technique in dental casting. Casting obtained by his technique resulted in intimate adaptation of margins of the casting with the finishing lines of the prepared teeth.
The introduction of ceramo-metal technology made the use of higher melting temperature alloy necessary to withstand the firing cycle of porcelain without noticeable distortion.

The phosphate-bonded investment fulfils these requirements. Initially, phosphate-bonded investment was treated with the same technique as used with the gypsum- bonded investment using metal ring.

Today, 3 methods of compensation for the metal shrinkage on cooling are in regular use: (1) setting expansion of the investment, (2) hygroscopic expansion of the investment, and (3) thermal expansion of the investment[32].

The metal casting ring restricts the thermal expansion of the investment because the thermal expansion of the ring is less than that of the investment. To compensate for this limitation, an asbestos liner was recommended[33]. The asbestos liner that was in use for many years was abandoned because asbestos is associated with carcinogenesis. Paper ceramic liners are used as a substitute[34].

The phosphate-bonded investments fulfil these requirements. These are investments where the binder is phosphate compounds. The thermal expansion curves of phosphate-bonded investments show more irregularities than the gypsum bonded investments[35]. Initially, phosphate-bonded investments were treated with the same techniques as used with the gypsum-bonded investments.
The need of the casting ring for the phosphate-bonded investments was not questioned, because its use was a standard procedure. The use of the casting ring was challenged with the introduction of a ringless technique initially for phosphate-bonded investments for removable partial denture frameworks and, recently, for conventional fixed restorations and even experimentally for implant-connected frameworks. The high strength of the material makes it possible to abandon the use of the casting ring. The ringless techniques are easier, less expensive, and give clinically acceptable castings[36].

V. CAD-CAM TECHNOLOGY

In 1971, the CAD/CAM processed to restorative dentistry and, in 1983, produced the first CAD/CAM dental restoration. Other researchers, including Aoki, Rekow and Caudill, were instrumental in developing this technology for dental systems.
Brandestini and Mörmann, in 1985, then used this process to develop CERAC (Siron, Bensheim, Germany), one of the first commercial CAD/CAM dental system for making ceramic inlays. Dental applications of CAD/CAM technology in dentistry remained restricted to finished ceramic restorations, such as inlays and crowns, for nearly 2 decades[37].

For CAD/CAM restorations, the generally acceptable marginal gap discrepancies rangebetween 50 to 100 µm, because this process decreases the possibility of human error and theinaccuracy inherent in different restoration materials[(36)]. Advances in dental ceramic materials andprocessing techniques, especially the development of CAD/CAM systems and milling technology,have facilitated the use of dental ceramics with superior physical properties[38]. In addition,CAD/CAM systems do not require fabrication steps such as waxing, investing, and casting.However, the use of these new technologies requires other new procedures, including scanning,software design, milling, and material processing, that require a considerable learning curve.

CAD/CAM systems are available in 3 different production approaches, depending on theirlocation: chairside, dental laboratory, or centralized milling center.In the first approach, thedigitalization instrument is an intraoral camera, which substitutes for a conventional impression.

The milling procedures can be undertaken in a dental office when the restorative material is resin,nanoceramic resin, or lithium disilicate blocks, but when the restorative material is pre-sinteredzirconia, dental laboratory equipment must be used. In the second approach, a definitive cast isfabricated from a conventional impression and is transferred to the laboratory[39].

Three-dimensionaldata are produced from the definitive die with a scanner, and the data are processedwith design software and sent to the milling machine. In the third approach, data sets produced inthe dental laboratory are sent to the production center for fabrication with the CAD/CAM device,and the restorations are returned to the dental laboratory[39].When CAD/CAM technology is used to make all-ceramic restorations, the fit can be set for each abutment tooth with software that customizes the marginal gap for the clinical situation.

The ability of CAD/CAM technology to implement the predetermined fit depends on the accuracyof the entire system including the scanning device, milling material, and milling unit. It also relieson exact dimensional prediction to compensate for sintering shrinkage. The CAD/ CAM techniqueis an economical and reproducible method which has been demonstrated to improve marginal fit[40]. Most used dental CAD system is listed in table 1.

Table 1. Most widely used dental CAD system.

CAD System	Manufacturer	File output
3Shape	3Shape	Propietary/STL
ARTI / Modelliere	Zirkonzahn	STL
CeraMill	Amann Girbach	STL
Cercon Eye/Art	Dentsply	Propietary
Cerec	Sirona	Propietary
Delcam	Delcam	STL
Dental Wings	Dental Wings	STL
E4D	Planmeca	Propietary/STL
Exocad	Exocad	STL
InLab	Sirona	Propietary/STL
Procera	Nobel Biocare	Propietary/STL

A technique for the fabrication of copy milled ceramic restorations has been presented. Both direct and indirect fabrication techniques of inlays, on-lays, veneers, and crowns are possible. A copy milling machine can mill accurately fitting restorations with a marginal gap of 50 microns. The machine uses premanufactured porcelain blanks, which have improved physical properties over conventional porcelains used in standard techniques. Recently, the ability to mill In-Ceram crowns from pre-sintered alumina blocks has been added to the system. The copings are veneered with aluminous porcelain as in the conventional In-Ceram technique[41]CAM milling technology is often referred to as subtractive process, as milling involves taking a block of material and cutting away everything that is not necessary until the final restoration emerges.[42].

VI. LASER SINTERING TECHNOLOGY

Laser sintering process was first introduced by Deckard and Beaman[43]. Laser sintering is also referred to as ‘‘3D printing’’ because it builds up framework in a series of successively thin layers (0.02-0.06 mm)[44]. A high-powered laser beam is focused onto a bed of powdered metal and these areas fuse into a thin solid layer. Another layer of powder is then laid down and the next slice of the framework is produced and fused with the first. When all the layers have been built up, the solid copings and bridge frameworks are taken from the machine, sand blasted, polished, inspected and ultrasonically cleaned.

Laser sintered crowns were compared with conventionally fabricated crowns for internal fit in an in vivo study. Marginal gap found in this study was on an average less than 65 µm and this was comparatively lesser than the marginal gaps of 81-136 µm found in all ceramic restorations[45]. The gaps found in this study for laser sintered crowns were much lower than originally reported acceptable marginal gap widths (150-125 µm)

Anders Ortorp evaluated and compared marginal gap and internal fit in an in vitro study. A total of 32 three unit fixed dental prostheses were fabricated in Co-Cr alloy using conventional lost method (LW), milled wax with lost-wax method (MW), milled Co-Cr(MC) and DLMS. Best fit was found in the DLMS group followed by MW, LW and MC. In all the four groups, best fit on abutments was along the axial walls and the largest discrepancy was occlusal[46].

Several in vitro techniques have been suggested for measuring the marginal fit alone or in combination with the internal fit of crowns. Among the destructive methods used, the specimens are sectioned then studied under an optical microscope or a scanning electron microscope (SEM). Alternatively, non-destructive methods have been used, including the stereomicroscope and image analysis, restricted to marginal evaluation.

VII. CEMENTATION

Incomplete seating of the crown during cementation may result in failure of an otherwise adequate restoration.The marginal adaptation of a crown is crucial for the success of the restoration. However, there is no correlation between the pre-cementation marginal fit and post-cementation marginal seal because for the cement.The more accurately the casting fits the prepared tooth, the more difficult it is for the cement to escape from the inner surface of the prepared tooth[47].

According to Hollenback, a minimum of 25µm relief on the axial walls of the casting is necessary or the crown will fail to seat by approximately 100µm[48].

The adverse effects of viscous luting cements, variation in marginal designs, magnitude of seating force and seating aid materials may complicate crown seating during cementation. The acquisition of cement space by applying a die spacer has been advocated by several studies to enhance the complete seating of the crown during cementation.

When die spacer was not applied, the increase of seating force from 5lb to 30lb resulted in significant improvement in metal crown seating[49]. According to Jorgersen, an increase in seating force significantly reduces the cement film thickness until 12lb of has been reached.

Many researchers have studied the effects of different luting agents (zinc phosphate, glass ionomer, and resin cements) on the retention and fitting of full cast crowns. These studies show that the best fit is obtained with glass ionomer cements. On the other hand, resin cements provide better retention, but also show greater vertical discrepancies of marginal fit. These concerns have led to the creation of several techniques that ensure an adequate space for the cementing agent, without losing retention of the final restoration[50].

The cement thickens with time, both time and setting time influences the seating and marginal fit. The delay in applying the seating force reduces the quality of cementation. Within the time frame in which the cement is clinically used, a 20 second delay can cause an increase of 0.02mm and a 2µm marginal discrepancy[51]. Analysis of these findings suggests that cementation could significantly increase the marginal discrepancy.

CONCLUSION

Generally, marginal fit of crowns from issuing manufacturing systems are clinically acceptable. Hence, selection of the manufacturing system should not be based primarily on marginal accuracy but rather the system's ability to provide adaptation of the material to the clinical and esthetical requirement.

Factors that are likely to affect the marginal fit are, finish line configuration, the value of the cement space and cementation.

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