

# Effect Of Two Cavity Designs On Fracture Resistance Of Indirect Composite Inlays Using Different Materials: An In-Vitro Study

Sunanda Gaddalay, Pratheeksha S

(Department Of Conservative Dentistry And Endodontics/ Rajiv Gandhi University Of Health Sciences, India)  
(Department Of Conservative Dentistry And Endodontics/ Rajiv Gandhi University Of Health Sciences, India)

---

## Abstract:

**Background:** Extensive Class II mesio-occluso-distal (MOD) cavity preparations significantly compromise the structural integrity of posterior teeth due to the loss of both marginal ridges, leading to increased cuspal deflection and susceptibility to fracture under occlusal loading. Indirect composite inlays have been advocated as a conservative alternative to full-coverage restorations for such defects, offering improved polymerization, enhanced mechanical properties, and reduced polymerization shrinkage stress compared to direct restorations. The biomechanical performance of restored teeth is influenced not only by the restorative material but also by cavity design. Modifications such as proximal flaring may improve enamel bonding surface area and facilitate better stress distribution at the cavosurface margin. However, additional removal of tooth structure may also adversely affect fracture resistance. Thus, optimizing cavity configuration is critical to achieving long-term clinical success.

Recent advancements in laboratory-processed composite systems, including micro-ceramic reinforced materials such as Ceramage and composite systems like GC Solare, have improved mechanical properties and wear resistance. Nevertheless, evidence comparing the combined influence of cavity design modification and material type on fracture resistance remains limited.

**Materials and Methods:** 64 permanent maxillary premolars were included in this study. Class II MOD cavities were prepared on all the teeth. The samples were randomly divided into two groups based on the type of indirect composite material used Ceramage and GC Solare. Each group was further subdivided into two groups based on the modification in the cavity design with flare, without flare. Cavity modifications were done accordingly. Putty wash impression were taken and dies were prepared for all the teeth.

Indirect inlay restorations were fabricated as per manufacturer's instructions using the two study materials. Final polymerization was performed in the curing oven at 100degree Celsius for 15minutes. The restorations were cemented on their respective samples using 3M ESPE RelyX self cure adhesive resin cement. Samples were stored in normal saline at room temperature for 7days. Samples were tested for fracture resistance using a universal testing machine and values were recorded in Newtons. Statistical analysis was done using ANOVA test.

**Results:** Group IA exhibited the highest mean fracture resistance. A statistically significant difference was observed among the groups.

**Conclusion:** Class II MOD cavities with flare on premolars showed greater fracture resistance when restored with Ceramage indirect composite compared to GC Solare.

**Key Word:** Cavity design, Class II MOD cavities, Fracture resistance, Indirect composite inlays

Date of Submission: 03-03-2026

Date of Acceptance: 13-03-2026

---

## I. Introduction

In restorative dentistry, posterior restorations present strength-related challenges. Metallic inlays, particularly gold, were once regarded as the benchmark for posterior teeth restorations. However, the growing demand for esthetic restorations and the advent of minimally invasive dentistry have driven research towards developing advanced materials and techniques that mimic the natural appearance of healthy teeth<sup>1</sup>. Touati (1983) in France and James (1983) in the USA pioneered the concept of molded composite inlays, fabricated from an impression and subsequently bonded in the mouth.<sup>2, 3, 4</sup> Composite inlays offer a promising solution due to their natural aesthetics, environmental advantages, and favourable mechanical and biological properties. However, the development of composite inlays has required years of research and refinement.<sup>5</sup> Their manufacturing process remains intricate, necessitating a comprehensive understanding of impression techniques, composite materials, and bonding mechanisms.

Indirect composite inlays offer a popular alternative to traditional amalgam restorations providing enhanced aesthetics and bond strength.<sup>6</sup> However, their fracture resistance can be influenced by factors such as

the type of composite material employed, the cavity design, and the fabrication technique. The present study focuses on investigating the impact of material type and cavity design alterations on the fracture resistance of indirect composite inlays.

Class II mesio-occluso-distal cavities are a common type of dental restoration, often necessitating indirect composite inlays to restore form and function due to larger extent of the cavity. Fracture resistance is crucial to ensure restoration longevity and maintain tooth structure. It is influenced by factors such as type of material, cavity design, restoration thickness and occlusal forces etc.

While design of the cavity preparation plays a pivotal role in the fracture resistance<sup>7</sup> modifications in cavity design, such as varying the depth, width of the preparation, can profoundly impact the longevity and success of the restoration.<sup>8</sup> The flare is a critical aspect of Class II mesio-occluso-distal cavity preparations. By giving flare to the proximal box, the restoration is less likely to fracture or crack, as the forces are distributed more evenly.<sup>9</sup>

Various materials are available for fabricating indirect tooth-colored restorations which includes Clearfil CR Inlay (Kuraray)<sup>13</sup>, and Visio-Gem (ESPE-Premiere), Ceramage (Shofu), Tetric Ceram (Ivoclar Vivadent), Sinfony (3M ESPE). This study employed Ceramage and GC Solare, given the lack of existing research on the material characteristics of these two specific materials. Ceramage, a zirconium silicate micro-ceramic, creates indirect restorations with excellent light transmission and translucency, similar to natural teeth. Its composition of 73% zirconium silicate fillers makes it suitable for various anterior and posterior restorations.

GC Solare X composite is a versatile restorative material that balances aesthetics and physical properties, making it suitable for both anterior and posterior tooth restorations. It exhibits low shrinkage stress, high fracture toughness, and a low modulus of elasticity, rendering it suitable for posterior teeth indirect restorations.

Despite the widespread use of Ceramage and GC Solare X in dental restorations, a comparative analysis of their fracture resistance in flared and non-flared preparations is lacking, prompting the need for this investigation.

Henceforth the current study was performed which aimed to assess the impact of modification in the cavity design on the fracture resistance of class II MOD cavities for indirect composite inlay fabricated with two different materials.

The null hypothesis stated is that neither material type nor flaring would have a significant impact on the fracture resistance of MOD cavities.

## **II. Material And Methods**

**Study Design:** The present investigation was conducted as an experimental, in-vitro, comparative, and quantitative study.

**Study Location:** Department of conservative dentistry and endodontics, S B Patil Institute for Dental Sciences and Research, Bidar, Karnataka, India.

**Study Duration:** January 2025 to March 2025.

**Sample size:** 64 human permanent maxillary premolars.

**Sample size calculation:** Using SPSS software in accordance with previous studies.

**Subjects & selection method:** 64 human maxillary premolars

### **Inclusion criteria:**

- Teeth extracted for periodontal or orthodontic reasons were included.
- Teeth with completely formed apices.

### **Exclusion criteria:**

- Teeth with caries.
- Teeth with abrasions, erosions.
- Teeth with cracks, fractures.
- Teeth with previous root canal treated teeth.
- Teeth with resorption.

### **Procedure methodology:**

64 Permanent maxillary premolars extracted for periodontal and orthodontic reasons were chosen for the study and stored in 0.9% normal saline for study purpose. Teeth with caries/ fractures or cracks and endodontically treated teeth were excluded from the study.

Class II MOD cavities were prepared on all the teeth using cavity preparation burs mounted on a high speed handpiece. Uniform cavity dimensions with pulpal depth – 1.5mm, width – 1/3<sup>rd</sup> of the intercuspal distance, axial depth – 3mm, divergent axial walls with a taper of 15 to 20 degree, gingival seat width – 1mm, gingival bevel were incorporated.<sup>10</sup> The samples were randomly assigned into two groups based on the type of indirect composite material being used for inlay fabrication I- Ceramage(Shofu, Tokyo, Japan) and II – GC Solare (GC Corporation limited, USA) Each group was further subdivided into two groups A and B based on the inclusion of flare in the proximal box. Cavity modifications were done accordingly.

Putty wash impression were made and dies were prepared for all the teeth. Indirect inlay restorations were fabricated as per manufacturer’s instructions using the two study materials. Final polymerization was performed in the curing oven (Polymat lab composite curing unit by Delta, India) at 100degree Celsius for 15minutes. The restorations were cemented on their respective samples using 3M ESPE RelyX self adhesive resin cement. Samples were stored in thymol at room temperature for 7days.

The samples were tested for fracture resistance by subjecting them to axial compressive loading using a metal sphere of 5 mm diameter applied vertically and centered on the occlusal surface of the restoration at a crosshead speed of 0.5 mm/min in a universal testing machine (Lloyd Instruments LR 50K, AMETEK GmbH, Meerbusch, Germany). Fracture resistance were recorded in Newtons for each sample.

**Statistical analysis**

One-way ANOVA analysis showed that there were statistically significant differences among the groups. A pairwise comparison of fracture resistance among the groups was performed using Post hoc tukey test (p < 0.001).

**III. Result**

One-way ANOVA analysis showed that there were statistically significant differences among the groups. The mean and standard deviations for the fracture strength of the test groups are shown in Table 1.

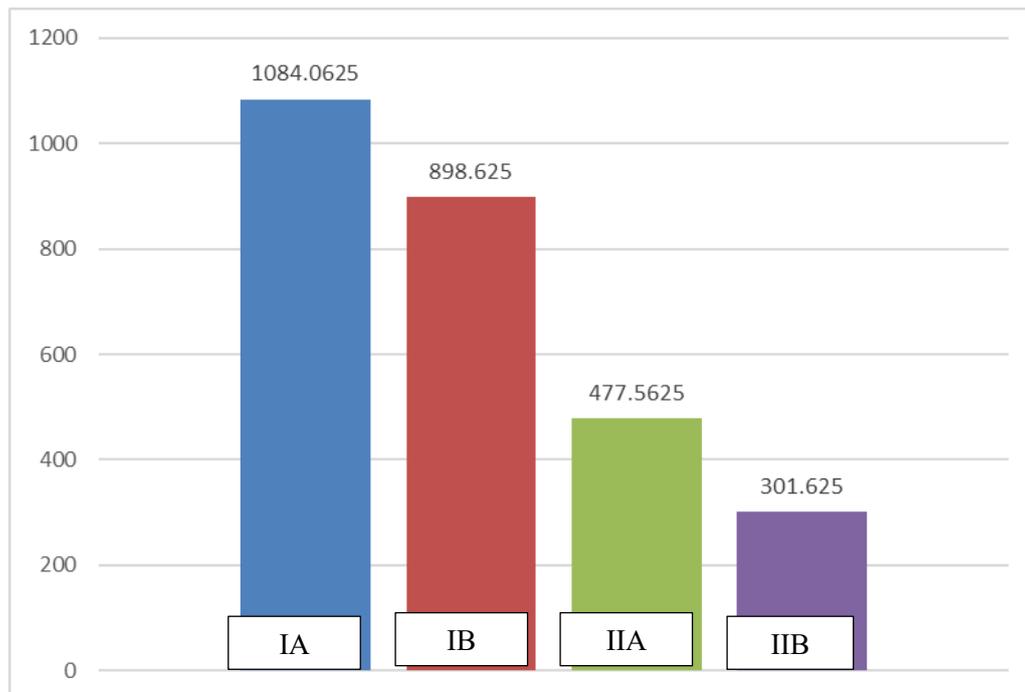
Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F value	P value
					Lower Bound	Upper Bound		
1	16	1084.0625	121.15030	30.28758	1019.5061	1148.6189	170.220	<0.001
2	16	898.6250	63.38441	15.84610	864.8498	932.4002		
3	16	477.5625	166.95946	41.73987	388.5961	566.5289		
4	16	301.6250	53.90470	13.47617	272.9012	330.3488		
<b>Total</b>	<b>64</b>	<b>690.4688</b>	<b>334.72377</b>	<b>41.84047</b>	<b>606.8572</b>	<b>774.0803</b>		

The fracture resistance values (in Newtons) were analyzed across four groups, with a total sample size of 64. Group IA exhibited the highest mean fracture resistance, followed by Group IB, Group IIA and Group IIB. A statistically significant difference was observed among the groups (F = 170.220, p < 0.001), indicating that fracture resistance varied significantly between them.

A pairwise comparison of fracture resistance values among the groups performed using Post hoc tukey test revealed statistically significant differences across all comparisons (p < 0.001). The confidence intervals for each comparison further confirm these differences, indicating a consistent trend in decreasing fracture resistance from Group IA to Group IIB.

Pairwise comparisons are depicted in Table 2.

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	185.43750	39.32086	.000	81.5313	289.3437
	3	606.50000	39.32086	.000	502.5938	710.4062
	4	782.43750	39.32086	.000	678.5313	886.3437
2	1	-185.43750	39.32086	.000	-289.3437	-81.5313
	3	421.06250	39.32086	.000	317.1563	524.9687
	4	597.00000	39.32086	.000	493.0938	700.9062
3	1	-606.50000	39.32086	.000	-710.4062	-502.5938
	2	-421.06250	39.32086	.000	-524.9687	-317.1563
	4	175.93750	39.32086	.000	72.0313	279.8437
4	1	-782.43750	39.32086	.000	-886.3437	-678.5313
	2	-597.00000	39.32086	.000	-700.9062	-493.0938
	3	-175.93750	39.32086	.000	-279.8437	-72.0313



Graphical representation of fracture Resistance Values (in Newtons) between groups.

#### IV. Discussion

Indirect composite inlays represent a sophisticated approach to restoring teeth that have been compromised by decay, trauma, or wear. These custom-fabricated restorations are created outside the mouth, utilizing advanced dental laboratory techniques, and are then bonded to the prepared tooth structure. By leveraging high-quality composite resin materials, indirect composite inlays offer a harmonious blend of durability and aesthetics, making them an attractive solution for patients seeking to restore their teeth while maintaining a natural appearance.

Indirect composite inlays are particularly well-suited for restoring large Class 2 cavities that are too extensive for direct restorations. Fracture resistance is a critical property of indirect composite inlays, directly impacting their durability and longevity. Fracture resistance can be influenced by factors such as the type of composite material employed, the cavity design, and the fabrication technique. The present research focuses on investigating the impact of material type and cavity design alterations on the fracture resistance of indirect composite inlays.

The design of the cavity preparation plays a pivotal role in the fracture resistance of the restored tooth.<sup>7</sup> Modifications in cavity design, such as varying the depth, width, and shape of the preparation, can profoundly impact the longevity and success of the restoration.<sup>8</sup>

According to Soares CJ et al. flared preparations exhibit superior resistance form compared to non-flared preparations, underscoring the significance of cavity design in promoting the durability and longevity of dental restorations.<sup>11</sup> Specifically, flared proximal boxes play a critical role in reducing the likelihood of restoration fracture by facilitating a more even distribution of forces.<sup>12</sup> Moreover, the incorporation of a flare can enhance marginal integrity by mitigating stress concentrations, thereby reducing the risk of marginal gaps and secondary caries.

It is essential to recognize, however, that resistance form is influenced by a multitude of factors beyond merely the presence or absence of a flare. The overall design and geometry of the preparation are pivotal in determining the resistance form of a restoration. This complexity is highlighted in various studies, which suggest that a comprehensive approach to cavity design, taking into account multiple variables, is necessary to optimize resistance form and ensure the long-term success of dental restorations.

Various materials are available for fabricating indirect tooth-colored restorations, including Clearfil CR Inlay (Kuraray)<sup>13</sup>, and Visio-Gem (ESPE-Premiere), Ceramage (Shofu), Tetric Ceram (Ivoclar Vivadent), Sinfony (3M ESPE) etc. Ceramage, an indirect composite resin, exhibits improved mechanical properties due to its unique composition and structure. Studies have consistently demonstrated that Ceramage possesses enhanced flexural strength and fracture toughness compared to other composite resins, attributed to its distinct formulation.

The key contributing factors are its ceramic fillers and polymer matrix. The incorporation of ceramic fillers, such as silicon dioxide and aluminum oxide, significantly contributes to Ceramage's improved mechanical

strength and durability. The polymer matrix of Ceramage is formulated with a unique blend of monomers, which plays a crucial role in enhancing its mechanical properties.

While Ceramage's mechanical properties are generally favorable, it is essential to acknowledge that differences in testing methods and conditions can yield varying results. This variability may impact the perceived performance of Ceramage, underscoring the need for standardized testing protocols and further research to fully elucidate its properties.

Compared to other dental restorative materials, such as Ceramage, GC Solare X has been shown to have lower fracture resistance.<sup>14</sup> GC Solare X may not be as durable as other materials, requiring more frequent replacements.<sup>15</sup> Henceforth irrespective of the cavity preparation design it showed least fracture resistance among all the groups.

Despite the sensitivity to shrinkage GC SolareX also has limited indications and color stability concerns.<sup>16,17,18</sup>

## V. Conclusion

Within the limitations of the study, Class II MOD cavities on premolars restored with Ceramage indirect composite in flared preparations demonstrated superior fracture resistance compared to those restored with GC Solare X (irrespective of the cavity modification).

## References

- [1]. Christensen GJ. Restorative Dentistry: A Changing Landscape. J Am Dent Assoc. 2005;136(9):1241-1244.2.
- [2]. Touati B. Inlays And Onlays In Composite Resins. Chirurgien-Dentiste De France. 1983;53(10):53-56.3.
- [3]. James DF. Molded Composite Resin Inlays. J Prosthet Dent. 1983;50(5):652-655.4.
- [4]. Fahl N. Aesthetic And Functional Composite Inlay And Onlay Restorations. J Esthet Restor Dent. 2006;18(2):75-88.
- [5]. Roulet JF, Degrange M. Composite Resin Inlays. In: Roulet JF, Degrange M, Editors. Adhesion: The Silent Revolution In Dentistry. Chicago: Quintessence Publishing; 2000. P. 231-242
- [6]. Davidson CL, De Gee AJ. Relaxation Of Polymerization Contraction Stresses By Flow In Dental Composites. J Dent Res. 1984;63(2):146-148.
- [7]. Tay FR, Lussi A, Pashley DH. Factors Contributing To The In Vitro Fracture Resistance Of Posterior Teeth Restored With Composite Resin. Dent Mater. 2004;20(7):654-661.3.
- [8]. Van Noort R, Van Der Voorde ME, Martin N. The Effect Of Cavity Preparation Design On The Fracture Resistance Of Teeth Restored With Composite. Dent Mater. 2011;27(6):587-593.4.
- [9]. Peutzfeldt A, Asmussen E. Clinical Relevance Of Polymerization Shrinkage In Posterior Resin Restorations. Eur J Oral Sci. 2004;112(2):151-156.5.
- [10]. Garber DA, Goldstein RE. Porcelain And Composite Inlays And Onlays. Chicago: Quintessence Publishing; 2001., 39-46.
- [11]. Soares, C. J., Et Al. (2006). "Effect Of Cavity Preparation Design On Fracture Resistance Of Teeth Restored With Composite Resin." Journal Of Dental Research, 85(10), 932-936.
- [12]. Hormati, A. A., Et Al. (2010). "Influence Of Proximal Box Design On Fracture Resistance Of Class II Composite Restorations." Journal Of Prosthetic Dentistry, 104(3), 171-177.3.
- [13]. Kara, H. B., Et Al. (2013). "Effect Of Cavity Preparation Design On Marginal Integrity Of Composite Restorations." Journal Of Dentistry, 41(10), 911-916.
- [14]. Jung M, Hundhausen F, Feldhaus KJ, Et Al. Mechanical Properties Of Ceramage And Other Composite Resins. J Dent Res 2003;82(12):942-6.2.
- [15]. Manufacturer's Data. GC Solare X Technical Product Profile. GC Corporation; 2015.
- [16]. Ferracane JL. Developing A More Complete Understanding Of Stresses Produced In Dental Composites During Polymerization. Dent Mater 2005;21(1):36-42.4.
- [17]. Kim SH, Et Al. Color Stability Of Dental Composite Resins After Immersion In Staining Solutions. J Dent Res 2006;85(11):1034-8.5.
- [18]. Bayne SC, Et Al. Update On Dental Composite Restoratives. J Am Dent Assoc 2003;134(5):587-97