

Comparative Evaluation of the Shear Bond Strength of Different Core-Veneer Restorative Systems: An In Vitro Study

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Abstract

Introduction: Porcelain-fused-to-metal (PFM) systems have long been the gold standard for fixing partial dentures (FPDs). The bond between the ceramic and the core depends on various factors, such as the oxide layer, the thermal expansion coefficients, and the alloy's microstructure. The longevity of any bilayer restoration depends critically on the bond strength between the aesthetic porcelain and the underlying core material. Given that the interfacial bond strength dictates the clinical survival of bilayer restorations, this study evaluated and compared the nominal shear bond strength across four distinct core-veneer restorative systems.

Methodology: A total of 40 standardised rectangular specimens (25 mm × 3 mm × 0.5 mm) of different alloy combinations were fabricated and equally divided into four groups. Group 1 is conventional cast Ni-Cr alloy, Group 2 is conventional cast Co-Cr alloy, Group 3 is direct metal laser sintered (DMLS) Co-Cr alloy, and Group 4 is CAD/CAM milled zirconia. Conventional Ni-Cr (Group 1) and Co-Cr (Group 2) core alloy specimens were fabricated using rectangular wax patterns obtained from smooth casting wax sheets of 0.5 mm thickness. Porcelain buildup was applied to all specimens in the central 8 mm, leaving 8.5 mm on either side, to a uniform thickness of 1 mm, followed by a ceramic firing cycle as recommended by the manufacturer. Each prepared specimen of veneered porcelain with core structure was subjected to shear force at a crosshead speed of 1mm/min on a universal testing machine (UTM). Loading was done till fracture occurred. The shear bond strength was calculated in megapascals (MPa).

Results: Maximum shear bond strength of 25.67 MPa was observed in Group 1, while a minimum of 2.54 MPa was observed in Group 2. To compare all groups, a one-way ANOVA was performed, which revealed a highly significant difference ($p < 0.001$) among the study groups. To make individual pairwise comparisons, Tukey's HSD post-hoc test was applied. This test revealed a highly significant difference in the mean shear bond strength between Group 1 and all other study groups. However, the comparison among all remaining study groups was not statistically significant.

Conclusion: Within the limitations of this in vitro study, the conventional Ni-Cr/IPS classic system had higher baseline nominal shear bond strength compared to the other core-veneer systems under immediate loading conditions. Because each restorative group utilised material-specific interfacial bonding protocols and distinct veneering ceramics, these findings reflect integrated system-level performance rather than isolated intrinsic core properties. Furthermore, the reported bond values represent nominal, unaged baseline values obtained without failure-mode classification. Long-term studies incorporating artificial ageing, cyclic fatigue loading, and fractographic analysis are essential before clinical recommendations can be drawn.

Categories: Oral Medicine, Healthcare Technology, Dentistry

Keywords: base metal alloys, cad/cam, cobalt-chromium, dmls, laser sintering, nickel-chromium, porcelain, shear bond strength, zirconia

Introduction

Porcelain-fused-to-metal (PFM) systems have long been a gold standard for fixed partial dentures (FPDs), providing high resistance and good aesthetics [1]. The oxide layer, the thermal expansion coefficients, and the alloy's microstructure determine the bond strength between the aesthetic porcelain and the core [2,3]. Nowadays, base-metal casting alloys, such as Ni-Cr and Co-Cr, which have been modified using computer-aided design and computer-aided manufacturing (CAD/CAM), direct metal laser sintering (DMLS) Co-Cr, and CAD/CAM-milled zirconia, are widely used [4].

The PFM system is associated with limitations, including decreased light transmission, gingival discolouration, allergic reactions, and the release of metallic ions [5]. Thus, to avoid these limitations, we

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used ceramic restorations such as zirconia, which have higher mechanical efficiency in terms of structural stability and a “transforming toughening” mechanism [6,7]. Because it has a very high refractive index, a layer of veneering porcelain over it helps achieve a natural aesthetic [8]. These base-metal and all-ceramic systems have distinct interfacial bonding challenges; thus, it is important to do focused comparative evaluation.

The longevity of any bilayer restoration depends critically on the bond strength between the underlying core material and the aesthetic porcelain. Choi et al. and Sreekala et al. have mentioned significant differences in bond shear strengths between metal-ceramic and zirconia-ceramic systems, while Bahri et al. did not report the same [9–11]. Furthermore, a lack of consensus persists regarding a unified testing protocol for measuring bond strength, with the shear test remaining the most prevalent method [12]. Given that interfacial bond strength dictates the clinical survival of bilayer prostheses, further comparative evaluation is warranted.

The purpose of the study was to evaluate and compare the nominal shear bond strength of four specific core-veneer restorative combinations, accounting for their substrate-specific interfacial conditioning and veneering protocols.

Materials And Methods

This in vitro study was conducted to evaluate and compare the shear bond strength of porcelain veneer to conventional cast nickel-chromium (Ni-Cr) alloy, conventional cast cobalt-chromium (Co-Cr) alloy, DMLS Co-Cr alloy, and CAD/CAM milled zirconia specimens at the Genesis Institute of Dental Sciences & Research (Ferozepur), Precision Ceramic Artz (Mohali), and CIPET (Amritsar), Punjab, India.

A total of 40 standardised rectangular specimens ($n = 10$ per group) were fabricated, in alignment with sample sizes conventionally utilised in preliminary in vitro bond strength investigations. An a priori sample-size calculation was not performed; however, a post hoc power analysis based on the observed effect size ($f = 0.73$, $\alpha = 0.05$) demonstrated a statistical power exceeding 90% for detecting overall omnibus differences among groups. The sample size and within-group variance are acknowledged as study limitations. The specimens were $25\text{ mm} \times 3\text{ mm} \times 0.5\text{ mm}$ and divided equally into four groups ($n = 10$). Group 1 includes conventional cast Ni-Cr alloy, Group 2 includes conventional cast Co-Cr alloy, Group 3 includes DMLS Co-Cr alloy, and Group 4 includes CAD/CAM milled zirconia.

Materials and armamentarium

Equipment employed featured a casting machine (Fornex T, BEGO, Germany), burnout and pre-heating furnaces, a 3Shape optical scanner (Denmark), an EOS M100 DMLS machine unit (Germany), a Roland DWX-50 milling machine, a TABEO sintering machine, a sandblasting unit, an Ivoclar Vivadent Programat P310 ceramic furnace, a digital carbon fibre composite vernier calliper (RoHS), and a universal testing machine (UTM, Dak System Inc., India).

The primary core and veneering materials evaluated in this study, along with their chemical compositions and coefficients of thermal expansion (CTE), comprised four distinct restorative systems. The conventional Ni-Cr alloy (StarLoy N, Dentsply, Germany) consisted of approximately 58.8% Ni, 24.5% Cr, 10.0% W, 4.0% Mo, 1.5% Si, 1.0% Fe, and trace elements (beryllium-free) with a CTE of $14.1 \times 10^{-6}\text{ K}^{-1}$ over the temperature range of 25–500 °C, veneered with IPS Classic porcelain featuring a matching CTE of $12.6\text{--}13.0 \times 10^{-6}\text{ K}^{-1}$. The conventional Co-Cr alloy (Mega-bond CP, Dentsply, Germany) had a nominal composition of ~61.0% Co, 27.5% Cr, 6.0% Mo, 2.0% Fe, 1.5% W, 1.0% Si, and trace elements (nickel- and beryllium-free), with a CTE of $14.2 \times 10^{-6}\text{ K}^{-1}$ over the temperature range of 25–500 °C, also veneered with IPS Classic porcelain. Similarly, the DMLS Co-Cr alloy (Powder Range CC ME, EOS, Germany) comprised ~63.8% Co, 24.7% Cr, 5.1% Mo, 5.4% W, and 1.0% Si (nickel- and beryllium-free; particle size: 20–45 μm), with a CTE of $14.3 \times 10^{-6}\text{ K}^{-1}$, paired with IPS Classic porcelain. Finally, the all-ceramic core consisted of pre-sintered CAD/CAM zirconia blanks (NEXZt.T, Sagemax, USA) composed of $\geq 91\%$ $\text{ZrO}_2 + \text{HfO}_2 + \text{Y}_2\text{O}_3$, 4.5–5.6% Y_2O_3 , and $\leq 0.5\%$ Al_2O_3 with a CTE of $10.5 \pm 0.5 \times 10^{-6}\text{ K}^{-1}$, which was veneered with IPS e.max Ceram possessing a compatible CTE of $9.4\text{--}9.6 \times 10^{-6}\text{ K}^{-1}$.

Methodology

Preparation of Conventional Metal Specimens (Groups 1 and 2)

Specifically, $25\text{ mm} \times 3\text{ mm} \times 0.5\text{ mm}$ rectangular wax patterns were harvested from milling wax blanks (Figure 1).

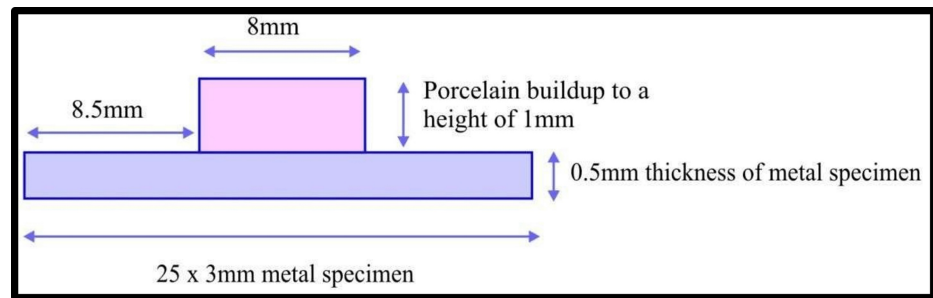


FIGURE 1: Specimen fabrication obtained from milling wax blanks

Recovered castings were cleaned of investment residue using airborne-particle abrasion, followed by sequential contouring and finishing using tungsten carbide burs and medium-grit ceramic-bonded stones under copious water irrigation. Specimens were polished using rubber polishers at low speed ($< 10,000$ rpm) and verified for dimensional precision ($25\text{ mm} \times 3\text{ mm} \times 0.5\text{ mm}$) using a digital vernier calliper. Prior to veneering, the core bonding surfaces were sandblasted with $100\text{ }\mu\text{m}$ Al_2O_3 at 0.25 MPa at a 45° angle from a distance of 10 mm for 10 sec , followed by ultrasonic cleaning in 95% ethanol for 10 minutes and air-drying. These dimensions were selected based on standard, well-established configurations for screening core-veneer interfacial adhesion. However, this geometry does not simulate the complex curved margins, circumferential stress distribution, or anatomical porcelain thickness transitions of complete crowns.

Preparation of DMLS Co-Cr Specimens (Group 3)

Specimen dimensions were made using CAD software, and the design files were loaded into the DMLS system. To prevent damage, all the specimens were subjected to a blasting pressure of 0.25 MPa (2.5 bar) for the cast and DMLS metal groups and 0.20 MPa (2.0 bar) for zirconia specimens, using $100\text{ }\mu\text{m}$ high-purity aluminium oxide particles. For this, the nozzle was maintained at a 45° angle at a fixed distance of 10 mm for 10 seconds . Afterwards, all the specimens were ultrasonically cleaned in 95% ethanol for 10 minutes and dried with oil-free compressed air.

Preparation of Milled Zirconia Specimens (Group 4)

We used the CAD software with an enlargement scale factor of ~ 1.25 (corresponding to approximately $20\text{--}25\%$ linear sintering shrinkage, calibrated using manufacturer-provided blank barcode data) to design Zirconia frameworks. Following sintering, zirconia specimens were shaped using diamond rotary instruments under water cooling at low speed, sandblasted at 0.2 MPa with $100\text{ }\mu\text{m}$ Al_2O_3 particles at a 45° angle, and cleaned ultrasonically in 95% ethanol (Figure 2).

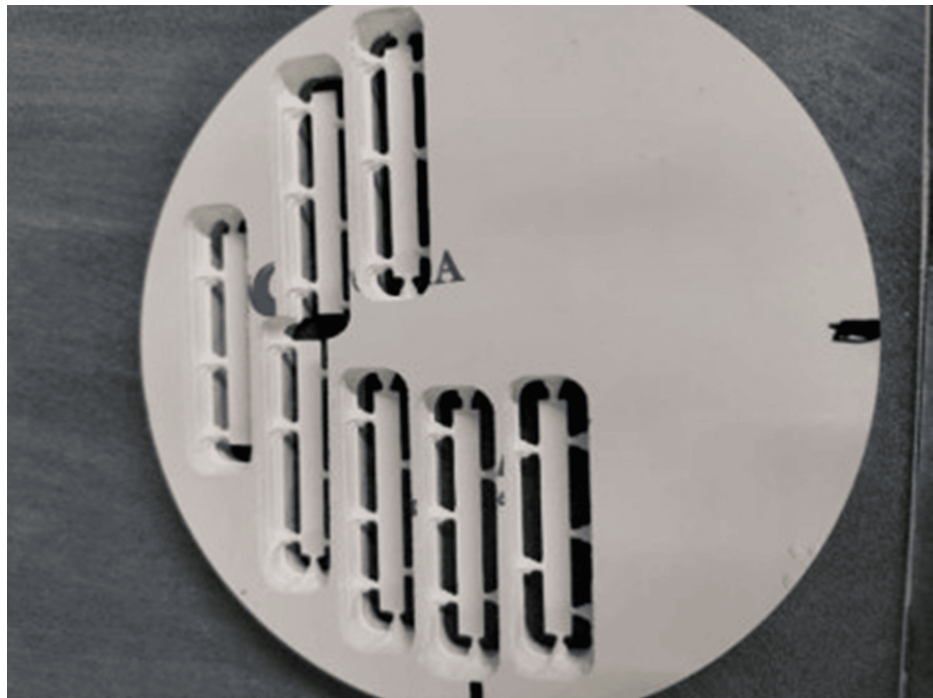


FIGURE 2: Milled zirconia specimens designed with the help of CAD software

Application of Veneer Porcelain

Ceramic firing schedules followed the respective manufacturers' specifications. For manufacturers (Groups 1-3, veneered with IPS Classic): opaque firing (initial temp: 403 °C; heating rate: 80 °C/min; final temp: 950 °C; hold time: 1 min under vacuum); dentin firing (initial temp: 403 °C; heating rate: 60 °C/min; final temp: 910 °C; hold time: 1 min under vacuum, slow cooling). For zirconia frameworks (Group 4, veneered with IPS e.max Ceram): dentin firing (initial temp: 403 °C; heating rate: 45 °C/min; final temp: 750 °C; hold time: 1 min under vacuum, slow cooling protocol to minimise residual thermal tensile stress). Because interfacial conditioning (application of Cerambond and an opaque layer on metal cores versus direct veneering on zirconia) and ceramic brands varied according to manufacturer specifications, each group was evaluated as an integrated core-veneer system rather than as an isolated substrate comparison.

Shear Bond Strength Testing

Each bilayer specimen was positioned in a customised rigid steel test fixture mounted on a UTM (5 kN load cell capacity; Dak System Inc., India). We applied a force using a chisel-shaped hardened steel stylus positioned 0.5 mm adjacent to the core-veneer interface at a 45° angle, with a crosshead speed of 1 mm/min, as shown in Figure 3.



FIGURE 3: Testing for shear bond strength on the universal testing machine

This 45° angle generates a mixed-mode stress distribution (combining interfacial shear, compression, and secondary tensile-bending components); the recorded fracture loads were converted to nominal shear bond strength (MPa) using the formula: $SBS = \text{Force} / \text{Area}$, where Force is the load recorded at the point of failure and Area is the bonded interfacial surface area. Loading was applied monotonically until catastrophic failure - the macroscopic setup during and immediately after load-induced debonding is illustrated in Figure 4.



FIGURE 4: Fractured specimen obtained after the application of load

However, because high-resolution stereomicroscopy or scanning electron microscopy (SEM) was not performed on individual debonded interfaces, reliable macroscopic failure-mode classification (distinguishing adhesive, cohesive, or mixed modes) could not be definitively executed across individual specimens; therefore, failure-mode classification was not performed in this investigation.

Statistical Product and Service Solutions (SPSS, version 21.0; IBM SPSS Statistics for Windows, Armonk, NY) software was used for statistical purposes. Descriptive statistics were computed for all four experimental groups, including means, standard deviations, standard errors, ranges, and 95% confidence intervals. Data distribution and variance were evaluated before inferential testing. The Shapiro-Wilk test was used to assess the normality of the groups ($p > 0.05$), and Levene's test ($F(3, 36) = 2.18, p = 0.108$) was used to assess homogeneity of variances. The overall difference in mean nominal shear bond strength among the four restorative systems was analysed via one-way analysis of variance (ANOVA), which revealed a statistically significant difference. Pairwise comparisons were subsequently performed using Tukey's HSD post-hoc test ($\alpha = 0.05$). Tukey's statistical tests were two-tailed, and a significance threshold of $p < 0.05$ was applied throughout the evaluation.

Results

A total of 40 specimens were fabricated and divided into four groups of 10 samples each based on the core material. The peak loading in Newtons at the fracture site for veneering porcelain across core materials is shown in Table 1.

Specimen	Group 1 (Ni-Cr/IPS Classic)	Group 2 (Co-Cr Cast/IPS Classic)	Group 3 (Co-Cr DMLS/IPS Classic)	Group 4 (Zirconia/IPS e.max Ceram)
1	255	275	180	329
2	286	91	119	214
3	547	419	137	159
4	552	290	275	146
5	215	146	218	187
6	303	277	337	389
7	616	212	213	365
8	392	61	217	287
9	415	185	203	158
10	385	378	225	200

TABLE 1: Peak load in Newtons (N) at fracture for veneering porcelain across core materials

Values represent individual fracture load recordings in Newtons (N) for each core-veneer system (n = 10 per system).

Peak loads at fracture ranged from 61 N to 616 N across systems, with the highest load recorded in Group 1 (Ni-Cr/IPS Classic) and the lowest in Group 2 (Co-Cr Cast/IPS Classic). Shear bond strength values of veneering porcelain to underlying core materials (MPa) are presented in Table 2.

Specimen	Group 1 (Ni-Cr/IPS Classic)	Group 2 (Co-Cr Cast/IPS Classic)	Group 3 (Co-Cr DMLS/IPS Classic)	Group 4 (Zirconia/IPS e.max Ceram)
1	10.62	11.46	7.5	13.71
2	11.92	3.79	4.96	8.92
3	22.79	17.46	5.71	6.62
4	23	12.08	11.46	6.08
5	8.96	6.08	9.08	7.79
6	12.62	11.54	14.04	16.21
7	25.67	8.83	8.87	15.21
8	16.33	2.54	9.04	11.96
9	17.29	7.71	8.46	6.58
10	16.04	15.75	9.37	8.33

TABLE 2: Shear bond strength values of veneering porcelain to underlying core materials (MPa)

Values are presented as individual nominal shear bond strength measurements in megapascals (MPa). Each restorative system comprised 10 specimens (n = 10).

Maximum nominal shear bond strength (25.67 MPa) was observed in the Ni-Cr/IPS Classic system (Group 1), and minimum (2.54 MPa) was observed in the cast Co-Cr/IPS Classic system (Group 2). The descriptive statistics of nominal shear bond strength across the core-veneer restorative systems are presented in Table 3.

Group	Restorative System	Mean $\pm$ SD (MPa)	SE (MPa)	Range (Min – Max) (MPa)	95% CI for Mean (MPa)
1	Conventional Ni-Cr/IPS Classic	16.52 $\pm$ 5.72	1.81	8.96-25.67	12.43-20.61
2	Conventional Co-Cr/IPS Classic	9.72 $\pm$ 4.86	1.54	2.54-17.46	6.24-13.20
3	DMLS Co-Cr/IPS Classic	8.85 $\pm$ 2.61	0.82	4.96-14.04	6.99-10.71
4	CAD/CAM Zirconia/IPS e.max Ceram	10.14 $\pm$ 3.81	1.2	6.08-16.21	7.42-12.86

TABLE 3: Descriptive statistics of the shear bond strength among study groups in terms of mean shearbond strength, standard deviation (SD), standard error of mean (SE), range, and 95% confidence interval

Data are presented as mean $\pm$ standard deviation (SD), standard error of the mean (SE), range (minimum to maximum), and 95% confidence intervals (CI) for the mean in MPa (n=10 per group).

The conventional Ni-Cr/IPS Classic system exhibited the highest mean shear bond strength (16.52 $\pm$ 5.72 MPa), followed by the CAD/CAM Zirconia/IPS e.max Ceram system (10.14 $\pm$ 3.81 MPa), the conventional Co-Cr/IPS Classic system (9.72 $\pm$ 4.86 MPa), and the DMLS Co-Cr/IPS Classic system (8.85 $\pm$ 2.61 MPa).

To compare all groups, a one-way ANOVA was performed, which revealed a highly significant difference ($p < 0.001$) among the study groups, as shown in Table 4.

Source of Variation	Sum of Squares	df	Mean Square	F-value	P-value
Between Groups	371.736	3	123.912	6.384	0.001*
Within Groups	698.798	36	19.41	-	-
Total	1070.534	39	-	-	-

TABLE 4: Comparison of all groups using one-way analysis of variance (ANOVA)

One-way ANOVA comparing mean nominal shear bond strengths across the four restorative systems. *Statistical significance was established at two-tailed $p < 0.05$.

One-way ANOVA demonstrated a statistically significant difference in mean nominal shear bond strength across the four core-veneer restorative systems ($F(3,36) = 6.384$, $p = 0.001$). Subsequent Tukey's HSD post-hoc pairwise analysis showed that Group 1 had significantly higher shear bond strength than Group 2 ($p = 0.008$), Group 3 ($p = 0.002$), and Group 4 ($p = 0.013$). Pairwise differences among Groups 2, 3, and 4 did not attain statistical significance ($p > 0.05$). Pairwise comparisons of mean shear bond strength are shown in Table 5.

Group I	Group J	Mean Difference (I-J)	SE	P-value	95% CI
Group 1	Group 2	6.800	1.970	0.008*	1.493-12.107
Group 1	Group 3	7.685	1.970	0.002*	2.378-12.992
Group 1	Group 4	6.383	1.970	0.013*	1.076-11.690
Group 2	Group 3	0.885	1.970	0.969	-4.422-6.192
Group 2	Group 4	-0.417	1.970	0.997	-5.724-4.890
Group 3	Group 4	-1.302	1.970	0.911	-6.609-4.005

TABLE 5: Individual pair-wise comparisons of the mean shear bond strength using Tukey's HSD post-hoc test

Tukey's honestly significant difference (HSD) post hoc test was performed following a one-way ANOVA for pairwise comparison of mean shear bond strength between groups. Mean differences are expressed in MPa. A two-tailed p-value <0.05 was considered statistically significant.

*Denotes a statistically significant difference ($p < 0.05$).

Tukey's HSD post-hoc analysis revealed that the mean shear bond strength of Group 1 was significantly higher than that of all other study groups. However, comparisons among the remaining groups (Groups 2, 3, and 4) were not statistically significant.

A total of 40 specimens were fabricated and equally allocated into four groups according to the core material, with 10 specimens in each group ($n = 10$). The mean shear bond strength was highest in Group 1 (conventional Ni-Cr), at 16.52 ± 5.72 MPa, followed by Group 4 (CAD/CAM zirconia) at 10.14 ± 3.81 MPa, Group 2 (conventional Co-Cr) at 9.72 ± 4.86 MPa, and Group 3 (DMLS Co-Cr) at 8.85 ± 2.61 MPa.

One-way ANOVA demonstrated a statistically significant difference in mean shear bond strength among the four groups ($F(3,36) = 6.384$, $p < 0.001$). Tukey's HSD post-hoc analysis showed that Group 1 had significantly higher shear bond strength than Group 2 (mean difference = 6.80 MPa, $p = 0.008$), Group 3 (mean difference = 7.69 MPa, $p = 0.002$), and Group 4 (mean difference = 6.38 MPa, $p = 0.013$). No statistically significant differences were observed between Group 2 and Group 3 ($p = 0.969$), Group 2 and Group 4 ($p = 0.997$), or Group 3 and Group 4 ($p = 0.911$).

Discussion

Ni-Cr alloys with and without beryllium are among the largest groups used in ceramic-metal prostheses. In the case of a base-metal core structure, the chemical structure of the oxide layer at the interface primarily determines the strength of the bond between the core metal and the veneered porcelain. Sandblasting and cleaning improve the mechanical interlocking and wettability of the alloys. Nageshraj et al. have reported a strong bond at the metal-ceramic interface, thus ensuring short-term baseline mechanical resistance [13].

Dental base-metal casting alloys are carefully formulated to ensure biocompatibility and corrosion resistance. While occupational inhalation of nickel and beryllium particulates during industrial dry grinding or smelting poses respiratory toxicity risks, dental alloys must comply with ISO standards governing element release. The StarLoy N alloy evaluated here is completely beryllium-free, eliminating occupational hazards related to beryllium dust. Nonetheless, contact dermatitis and delayed Type IV hypersensitivity to nickel remain recognised clinical concerns. When nickel hypersensitivity is known to be present, cobalt-chromium alloys or high-strength ceramic restorations, such as zirconia, represent standard clinical alternatives [13]. Consequently, Co-Cr alloys were developed as safe alternatives to Ni-based alloys, offering favourable physical and mechanical properties without the risks associated with beryllium [11]. Wu et al. compared cast alloys with selectively laser-melted (SLM) Co-Cr alloys. They reported that SLM alloys exhibited significantly higher mechanical properties, although bond strength to porcelain did not differ significantly [14].

The bond between the core substructure and veneering porcelain determines the overall durability and clinical success of bilayer restorations. The mechanical performance and biocompatibility depend on our understanding of the microstructural, chemical, and physical dynamics at the interface and, in turn, will help achieve high aesthetic standards.

Choi et al., Abrisham et al., and Konka et al. observed that Ni-Cr systems exhibited higher interfacial bond strengths than Co-Cr systems [9,15,16]. In contrast, de Melo et al. and Singh et al. reported higher bond strengths in Co-Cr systems [12,17], whereas Bahri et al. recorded peak bond strength in zirconia systems [11].

In the present study, metal frameworks received an intermediate ceramic bonding agent (Cerambond) and an opaque layer veneered with IPS Classic, whereas zirconia specimens underwent direct veneering with IPS e.max Ceram in accordance with standard laboratory indications. Because these distinct interfacial conditioning agents, firing schedules, and veneering ceramics were specific to each core material, the measured shear bond strength reflects integrated system-level performance. The relative contributions of specific chemical bonding promoters, opaquer layer uniformity, and thermal expansion compatibility must therefore be interpreted within the context of each distinct multi-material assembly rather than attributed solely to the core substrate.

Akova et al. highlighted that stress concentrations at the porcelain termination site and residual thermal stresses arising from coefficient of thermal expansion (CTE) mismatches are critical determinants of bond performance [18]. Stable adhesion depends strongly on the quality of the interfacial oxide layer: an excessively thin layer may dissolve completely during firing, while an overly thick layer diminishes cohesive strength. Elements such as molybdenum, silicon, and aluminium in StarLoy N help prevent excessive oxide growth at elevated temperatures [17]. Beryllium-free Ni-Cr alloys are preferable, as they are not associated with occupational hazards from beryllium dust; however, in patients with nickel hypersensitivity, we used Co-Cr or all-ceramic restorations [17]. Since we do not know the veneering ceramics and interface treatments across groups, these factors act as confounding factors in the study. The differences we observed cannot be attributed to the pure core alloy, as we did not study the chemical bonding agents, the opacifier layer thickness, or the ceramic thermal contraction characteristics of the specimens.

Oh et al. reported that, for metal cores, both substructure thickness and porcelain application techniques determine fracture strength; however, for zirconia cores, the fabrication method is the dominant factor [19]. Using aluminium oxide (Al₂O₃) on the surface improves wettability and mechanical retention by increasing surface area and roughness. However, sandblasting parameters - such as particle size, pressure, and duration - must be carefully controlled to prevent microcrack formation [20]. Effective decontamination of the core surface is also important to maintain a uniform porcelain adaptation [5].

Zirconia (yttria-stabilised polycrystalline tetragonal zirconia) has gained widespread popularity in restorative dentistry due to its high flexural strength, transformation toughening mechanism, and tooth-colored appearance [21,22]. Unlike metallic frameworks, which rely heavily on chemical bonding via surface oxide formation and mechanical micro-interlocking, the retention of the veneering ceramic to this polycrystalline ceramic core depends predominantly on micromechanical retention achieved through surface conditioning and meticulous thermal expansion compatibility [14,22]. An appropriate CTE match between the zirconia core and the veneering porcelain prevents excessive transient and residual thermal stresses, reducing the incidence of ceramic chipping and delamination [22].

Several methodological limitations must be considered when interpreting these findings. Initially, the sample size of 10 specimens is small and warrants further study. The experiment compares only the integrative restorative systems because different interfacial conditioning agents and ceramic bands are required for metal and zirconia substrates. We could only report bond resistance rather than pure interfacial shear strength due to complex multi-axial stress states. We did not perform stereomicroscopy analysis of the specimens or quantify substrate surface roughness (Ra) following air abrasion. Testing was performed under dry, immediate laboratory conditions without thermocycling, mechanical fatigue, or aqueous storage, precluding direct extrapolation to long-term clinical intraoral survival.

Conclusions

The tested conventional Ni-Cr/IPS Classic restorative system showed higher nominal shear bond strength than other combinations under monotonic 45° compressive loading. However, because interfacial treatments and veneering ceramics differed between groups, this outcome reflects overall system behaviour rather than the isolated chemical superiority of the Ni-Cr core. Since no thermocycling, mechanical fatigue, or failure-mode analysis was done, these findings cannot be extrapolated to predict intraoral longevity or clinical prosthesis survival.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Manmohit Kumar, Kamaldeep Sharma , Reeta Jain, Gurmeet K. Viridi, Sumit Chopra , Shanta Chopra

Acquisition, analysis, or interpretation of data: Manmohit Kumar, Kamaldeep Sharma , Reeta Jain, Gurmeet K. Viridi, Sumit Chopra , Shanta Chopra

Drafting of the manuscript: Manmohit Kumar, Kamaldeep Sharma , Reeta Jain, Gurmeet K. Viridi, Sumit

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Critical review of the manuscript for important intellectual content: Manmohit Kumar, Kamaldeep Sharma , Reeta Jain, Gurmeet K. Virdi, Sumit Chopra , Shanta Chopra

Supervision: Manmohit Kumar, Kamaldeep Sharma , Reeta Jain, Gurmeet K. Virdi, Sumit Chopra , Shanta Chopra

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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