Clinical Evaluation of CAD/CAM Indirect Zirconia Restorations of Severely Destroyed Vital Teeth in the Posterior Area – Early Clinical Results

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Background: Dental applications of CAD/CAM concept have been available for almost 30 years. They have allowed dentists to work with novel materials with better properties. One of these materials is zirconia ceramic.

Aim: To evaluate prospectively the longevity of CAD/CAM indirect zirconia restorations of severely destroyed vital molars and to study the risk factors associated with restoration failures.

Materials and methods: Thirty-two indirect zirconia restorations were made in 19 patients. The treated teeth were extremely destroyed vital molars. Thermal and electrical tests for pulp vitality were performed for all teeth. Radiographs were made pre-operatively, post-operatively, and at the 6-month recall. Cvar and Ryge criteria were used for direct clinical evaluation of each restoration at the 6-month recall.

Results: All 32 zirconia restorations were evaluated at 6 months. As per Cvar and Ryge criteria, discrepancies were found in two of the cases: postoperative sensitivity in only one of the teeth immediately after cementing the restoration; a partial fracture of one of the restorations after six months. Good marginal and gingival adaptation of the indirect restorations, good periodontal condition and no periapical lesions were observed clinically and radiographically. The thermal and electrical pulp tests were within the normal range for vital posterior teeth.

Conclusions: The present study suggests that the new restorative zirconia materials are promising clinical alternative. They can give the clinicians a broader scope of opportunities in the treatment of their patients, aiming at more sustained and improved results.

BACKGROUND

Restorative work is the core business of dentistry. It has been estimated that 500 million direct dental restorations are placed each year worldwide¹, with the composite resin restorations predominating². Obturations are placed due to caries, fractures, or tooth wear, and a high number of restorative procedures are indicated to replace restorations that have failed.³ As an alternative to direct restorations, indirect restorations may be placed. Because of the increased esthetic demands of patients, most indirect restorations at present are likely to be made from ceramic materials.

The rapid progress of computer technologies has revealed a new digital world of unlimited possibilities. Dental applications of CAD/CAM (computer-aided design/computer-aided manufacturing) have been available for almost 30 years, and a considerable amount of in-vitro and in-vivo research has been published documenting the clinical efficacy and longevity of restorations fabricated using CAD/CAM.⁴ CAD/CAM in dentistry has been particularly useful in enabling the fabrication of custom, patient-specific restorations and prosthetics without having to use traditional analog dental laboratory methods.⁵ Modern CAD/CAM systems expedite the clinical appointment and improve workflow efficiency.⁶

All these circumstances make possible the use of new materials with better properties. The ceramic materials used include feldspathic porcelain, leucite-reinforced pressed ceramics, lithium disilicate, and various types of machinable, milled zirconia ceramics.

Our study focused on the clinical performance of yttrium-oxide partially stabilized zirconia (YPSZ)
ceramics, also known as yttrium tetragonal zirconia polycrystals (Y-TZP). Y-TZP exhibits exceptional fundamental properties of great interest to biomedical engineering, such as high strength, higher fracture toughness than other ceramics (between 8 MPa·m$^{1/2}$ and 10 MPa·m$^{1/2}$), hardness, wear resistance, good frictional and non-magnetic behaviour, electrical insulation, low thermal conductivity, corrosion resistance in acids and alkalis, modulus of elasticity similar to steel, and coefficient of thermal expansion similar to iron. In addition, contemporary Y-TZP materials are a promising optical material with a broad range of transparency (0.2–8 mm) and high translucency. Therefore, these ceramics are becoming popular in restorative dentistry when full-contour zirconia restorations are required, making the esthetic veneering porcelain unnecessary.\(^7\)

Our hypothesis is that the protocol proposed in our study for the preparation and cementation of indirect zirconia restorations will lead to long-lasting marginal integrity without any risk of fracture and excellent clinical survival of the onlays/overlays produced.

**AIM**

The aim of the present study was to evaluate prospectively the longevity of CAD/CAM indirect zirconia restorations of extremely destroyed vital molars and to study the risk factors associated with restoration failures.

**MATERIALS AND METHODS**

Thirty-two indirect Y-TZP zirconia restorations were placed on the molars of 19 patients, both female and male. Their age range was between 18 and 65 years. The treated teeth were severely destroyed molars. Of them, 12 were maxillary and 20 were mandibular molars with presence of proximal contacts and antagonists. All teeth showed no response to percussion (both horizontal and vertical). Patients with poor oral hygiene, periodontal disease, abrasion, any para-functional habits or abnormal occlusion were excluded from the study. The nature and objectives of the study, as well as all restorative procedures, were explained to the patients. Written informed consents approved by the Research Ethics Committee of the Medical University - Plovdiv, Bulgaria were obtained from all patients prior to treatment (P-1802, 14 July, 2015).

Thermal and electrical tests for pulp vitality were performed on all teeth. All results of the two tests were within the normal range for vital posterior teeth. Pre-operative and post-operative (after cementation) radiographs were taken, as well as 6 months following the procedure. Intraoral colour digital photographs were taken in each patient at the same stages of treatment as a permanent record for subsequent evaluation and later reference (Fig. 1).

Appropriate local anesthesia was administered pre-operatively, unless declined by the patient. The shade of each tooth to be restored was recorded while the tooth was moist according to the Vita Classical shade guide. After conventional preparation of the treated teeth for placement of an indirect ceramic restoration, a digital impression of the preparation, the adjacent teeth, the antagonist and the occlusion was taken by means of an intraoral scanner (Trios 3Shape). The data obtained were sent to the lab computer. The intraoral scan was used for modelling the restorations and the virtual articulation by the CAD software. In the end, the restoration was treated for milling by the CAM module (a vhf machine). The restorations were milled from pre-coloured UTML (ultra-translucent multi-layered) KATANATM Zirconia discs (Kuraray Noritake Dental Inc.), available in two different shades, A3 and A2, according to the Vita Classical shade guide.

After sintering according to a programme specially designed by the manufacturers, the restorations were additionally stained where needed and glazed.

The pretreatment procedures and cementation of all indirect zirconia obturations were performed according to an individual protocol meeting the manufacturer’s requirements. The inner surface of the zirconia obturations was sandblasted with particles of 50 μm Al$_2$O$_3$ under a pressure of 2 bars (0.2 MPa) for 5 sec at an angle of 90° and distance of 10 mm between the device and onlay/overlay. After isolation and medication of the cavity, a Ketchant Syringe was applied for 10 sec. following rinsing and drying of the cavity walls. Panavia V5 Tooth Primer was applied to the cavity for 20 sec, which was subsequently dried. The zirconia surface was also processed using Clearfil Ceramic Primer Plus and dried. The restorations were cemented with dual-cured resin-based cement (PanaviaTM V5, Kuraray Noritake Dental Inc.). The cement and all primers used contained MDP-monomer as a component (Fig. 2).

The U.S. Public Health Service (USPHS)/Cvar and Ryge criteria were used for direct clinical evaluation of each restoration immediately after cementation and at six months. For each criterion A (Alpha) means a high degree of clinical accept-
ability, while B (Bravo) and C (Charlie) mean a progressive decrease in it (Table 1). All results were recorded in specially designed individual cards for each patient.

STATISTICAL ANALYSIS
We used the two-related-samples test to compare the distributions of the clinical features studied at baseline and after 6 months by applying the Wilcoxon signed-rank test. The level of significance was \( p < 0.05 \). All p-values are two-tailed.

RESULTS
At six months all 32 zirconia restorations were evaluated. The following Cvar and Ryge criteria for direct clinical evaluation of a restoration were observed: color match; marginal discoloration; marginal adaptation; anatomical form; development of secondary caries; proximal contact; postoperative sensitivity; loss or fracture of the indirect zirconia restoration.

Regarding color match, 32 of the examined restorations appeared to match the shade and translucency of adjacent dental tissues in both periods of observation - after cementing the restoration and 6 months after the procedure.

No visual evidence of marginal discoloration was observed in all cases – the colour of the area did not differ from that of the restorative material or the adjacent dental structures in both observation periods of the study. There was a good marginal adaptation of the restoration - the explorer did not catch when drawn across the surface of the restoration toward the tooth, there was no visible

Figure 1. Pre-operative condition of the treated molars.

Figure 2. (A, B, C) Indirect zirconia restoration – post-operative photos and radiographs after the cementation.
### Table 1. Modified USPHS criteria

| Criteria                        | Test procedure                                  | USPHS score                                      |
|--------------------------------|-------------------------------------------------|-------------------------------------------------|
| **Color match**                | Visual inspection with mirror                   | The restoration is perfectly matched for color shade | Alpha (A)                          |
|                                |                                                  | The restoration is not perfectly matched for color shade and slightly differs from the natural tooth | Bravo (B)                         |
|                                |                                                  | The restoration is unacceptable for color shade  | Charlie (C)                        |
| **Cavo-surface marginal discoloration** | Visual inspection with mirror                   | Absence of marginal discoloration               | Alpha (A)                          |
|                                |                                                  | Superficial, usually localized, removable marginal discoloration | Bravo (B)                         |
|                                |                                                  | Evident marginal discoloration, penetrated toward the pulp chamber | Charlie (C)                        |
| **Secondary caries**           | Visual inspection with mirror, explorer, and radiograph | No evidence of caries                           | Alpha (A)                          |
|                                |                                                  | Evidence of caries along the margins of the restoration | Bravo (B)                         |
| **Anatomic form**              | Visual inspection with mirror and explorer      | The restoration is a continuation of existing anatomic form | Alpha (A)                          |
|                                |                                                  | Generalized loss of material, but clinically acceptable obturation (50% from the cavity’s margins can be explored, there is no exposed dentin) | Bravo (B)                         |
|                                |                                                  | The loss of material is under the enamel-dentin junction (clinically unacceptable obturation) | Charlie (C)                        |
| **Marginal integrity**         | Visual inspection with mirror and explorer      | A slight transition between the obturation and the cavity walls. | Alpha (A)                          |
|                                |                                                  | The explorer catches and there is visible evidence of a crevice, but only in the enamel | Bravo (B)                         |
|                                |                                                  | The explorer penetrates crevice defect extended to the dento-enamel junction | Charlie (C)                        |
| **Approximal contact**         | Visual inspection with mirror, explorer, and separation | The approximal contact is good, the floss can pass | Alpha (A)                          |
|                                |                                                  | The approximal contact is weak, the floss can pass without effort | Bravo (B)                         |
|                                |                                                  | Lack of approximal contact                      | Charlie (C)                        |
| **Gross fracture**             | Visual inspection with mirror and explorer      | Lack of fracture; the restoration is intact and fully retained | Alpha (A)                          |
|                                |                                                  | Partial or localized loss of the restoration    | Bravo (B)                          |
|                                |                                                  | Full loss of the restoration                    | Charlie (C)                        |
| **Postoperative sensitivity**  | Questions to the patients                       | Absence of dentinal hypersensitivity during the treatment and at all recalls after it | Alpha (A)                          |
|                                |                                                  | Presence of dental hypersensitivity during the treatment and at all recalls | Bravo (B)                          |
crevice along the periphery of the restoration. The anatomic form of the zirconia restorations followed the existing natural form of the treated teeth. No development of secondary caries was observed in all cases. The proximal contacts were good, and could be identified on radiography immediately following cementation, as well as at six months.

Postoperative sensitivity was found in only one of the teeth immediately after cementing the restoration. The patient reported no postoperative sensitivity at the six-month recall.

A partial fracture was observed in one of the restorations after six months, but the restoration was still clinically acceptable and did not show signs of requiring a replacement.

The results are summarized in Table 2. The analysis by Wilcoxon’s test found no significant differences at baseline and after 6 months.

All teeth were controlled radiographically after cementing the zirconia restoration and at six months. The radiographs revealed good marginal and gingival adaptation of the indirect restoration, good periodontal condition and no periapical lesions (Fig. 3).

The thermal and electrical pulp tests at six months were within normal range for vital posterior teeth.

The results obtained by the study supported our hypothesis.

**DISCUSSION**

The results of the present study comply with the clinical indications for ceramic restorations - ceramic systems can be used preferably on anterior teeth, only zirconia has shown adequate mechanical resistance for both anterior and posterior restorations.8

Posselt and Kerschbaum reported 2,328 inlays and onlays placed in 794 patients and fabricated using CEREC.9 The Kaplan-Meier method of survival probability was 97.4% at five years, and 95.5% at nine years. The longest clinical study to date on CEREC restorations regularly evaluated over 18 years reported a Kaplan-Meier survivability of 95% at 5 years, 91.6% at 7 years, 90% at 10 years, and 84.9% at 16.7 years.10 Our study also found high clinical performance of indirect zirconia restorations, especially when restoring vastly devastated posterior teeth.

Clinical studies with limited sample size have also shown that factors related to patients and operators influence the clinical outcome of ceramic inlays/onlays.11,12 Every step in this process has a certain effect on the final outcome of the treatment. We also share the opinion that the operator’s skill in preparing the teeth and using the digital systems for taking impressions, modelling and milling the restoration required is of primary importance. Ninety-six percent of the restorations produced in the present study possessed the highest grade of clinical performance, resulting from the great precision of the intraoral scanner, the wide range of possibilities for design with the CAD software and the high accuracy of the CAM module.

Some factors related to the materials, such as ceramic properties or characteristics of the adhesive luting technique, have been investigated extensively in vitro.13-15 As far as the luting technique...
is concerned, the protocol specially designed to meet the manufacturer’s recommendations and the use of MDP-primers and MDP-containing cement led to high strength of the bond between the inert zirconia and the cavity. This has been pointed out by many studies emphasizing the effect of the MDP monomer on this bond.16

A review of specialized literature published recently was performed by Sulaiman et al.17 involving a total of 39,827 monolithic zirconia restorations, of which 3731 were anterior restorations (1952 complete-coverage single crowns; 1799 multiple-unit fixed dental prostheses) and 36,096 were posterior restorations (29,808 complete-coverage single crowns; 6288 multiple-unit fixed dental prostheses). The overall fracture rate within 5 years following placement was 1.09% for all restorations (anterior and posterior). Fracture rates were 2.06% for all anterior restorations and 0.99% for all posterior restorations. Fracture rates were 0.97% for anterior complete-coverage single crowns and 0.69% for posterior complete-coverage single crowns, and the combined fracture rate (anterior and posterior) was 0.71%. For multiple-unit fixed dental prostheses, 3.26% anterior and 2.42% posterior restorations had fractured, and the combined fracture rate (anterior and posterior) was 2.60%. It was concluded that in the relatively short period of 5 years, monolithic zirconia restorations displayed low fracture rates.

In our study, only one of the restorations fractured partially. The fractured obturation was still clinically acceptable and did not need to be replaced.

As far as ceramic inlay luting is concerned, postoperative hypersensitivity has been reported to be between 3% and 5% in recent clinical studies observing tooth-colored inlays.18-20 Nevertheless, annual failure rates of 1–1.5% are low, even over a long-term observation period.21,22 This low percentage of dental hypersensitivity was confirmed by our study as well, where only one of the teeth showed hypersensitivity after the cementation procedure. At six months, the patient did not report any hypersensitivity.

Research on utilizing different ceramic systems has shown a significant increase in color mismatch between the ceramic inlay and the dental structure over both a 3- and 5-year observation period.23,24 The decrease in the quality of color match over time may be attributed to occlusal adjustment of surface colorants in the ceramic restoration or the choice of the luting composite.25 In our study, no color mismatch was observed, either post-operatively, or at six months.

Nevertheless, some studies have disclosed marginal discrepancies in 40% of the restorations after 3 years26,27 and 74% of the restorations at the 10-year recall examination. Increase in marginal discontinuity has been caused by apparent wear of
the composite resin luting agent, but ditching has not been associated with significant incidence of caries in long-term studies. Microleakage has been shown to become more apparent with the aging of the restoration, and caries recurrence has been associated with patients having high caries activity. No marginal discrepancies or secondary caries were found within the six-month observation performed.

The use of toughened ceramics, such as yttria-stabilized zirconia, offers a more fracture-resistant application of all-ceramic crowns in the posterior region without sacrificing esthetic qualities. Our observations on the esthetics of the manufactured restorations confirmed this. All restorations were characterized by high esthetic qualities due to the use of a multi-layer material with high optical qualities and the precision of the colour calibrator of the intraoral scanner. In addition to the esthetic appearance, extensive laboratory testing to date has confirmed the strength and marginal fit of zirconia ceramics. Our study confirmed the results obtained on the superior mechanical properties of dental zirconia. Since the number of long-term clinical studies on the success rate and primary mode of failure is limited, their future investigation and development is strongly advisable.

CONCLUSION

The present study suggests that the new zirconia materials seem to be promising as restorative materials combining great mechanical properties with biological and optical ones. They are also a high technology decision, based on the rapidly developing CAD/CAM systems. These modern materials and systems give the clinicians the opportunity to apply digital innovations in the treatment of their patients, aiming at more effective, long-lasting and potentially good results. That is why more research in this area is needed, which would result in further development of modern dental medicine.

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Клиническая оценка непрямых циркониевых реставрационных конструкций с использованием технологии CAD / CAM для сильно повреждённых задних витальных зубов - ранние клинические результаты

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Введение: Применение технологии CAD / CAM в стоматологии стало широко доступным в течение последних почти 30 лет. Это позволяет стоматологам использовать инновационные материалы с более высокими показателями. Одним из таких материалов является циркониевая керамика.

Цель: Провести проспективную оценку продолжительности жизни непрямых циркониевых реставрационных конструкций с использованием технологии CAD / CAM при сильно повреждённых витальных молярах и исследовать факторы риска, связанные с неудачной реставрацией.

Материалы и методы: Тридцать две циркониевые реставрации были проведены 19 пациентам. Обработанные зубы являлись сильно повреждёнными витальными молярами. Температурные и электрические тесты на витальность пульпы проводились на всех зубах. Рентгенограммы были сделаны во время операции, после операции и при 6-месячном контрольном осмотре. Критерии Квара и Риджа (Cvar and Ryge) использовались при прямой клинической оценке каждой реконструкции при проведении шестимесячного контрольного осмотра.

Результаты: Все 32 циркониевые реконструкции были оценены по истечении 6 месяцев. Относительно критериев Квара и Риджа, расхождение установлено в двух случаях: послеоперационная чувствительность только одного из зубов сразу после нанесения цемента в реконструкцию; частичный перелом одной из реставрационных конструкций через шесть месяцев. Клинически и рентгенографически установлены хорошая маргинальная и десневая адаптация непрямых реставраций, хороший периодонтальный статус и отсутствие периапикальных поражений. Температурные и электрические тесты пульпы были в допустимых нормах для витальных задних зубов.

Выводы: Данное исследование показывает, что новые восстановительные материалы из циркония являются многообещающей клинической альтернативой. Они могут предоставить клиницисту более широкий спектр вариантов лечения пациентов для достижения более длительных и лучших результатов.