

# The longevity of restorations - a literature review

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## ABSTRACT

Dentists need to consider various factors when choosing restorative materials, with the longevity of restorations being one of the most important criteria. Replacement of failed restorations constitutes over 60% of operative procedures, leading to high annual costs. This literature review compares the survival rates of different restorative materials used for both direct and indirect restorations. A literature search was carried out using Pubmed to identify all articles on restorative materials published from 1974 to 2014, of which 22 were included in this review. For direct restorations, amalgam showed the highest survival rates (22.5 years), with an average survival rate of 95% over 10 years, followed by composite resins (90% over 10 years), and glass ionomer cements (65% over 5 years). For indirect restorations, gold restorations are still the “gold standard” with a 96% over 10 years survival rate, followed by porcelain-fused-to-metal crowns (PFM) (90% over 10 years), and all ceramic crowns (75-80% over 10 years). Amongst the ceramic restorations, eMax shows the longest survival rate (90% over 10 years), and Zirconia the lowest (88% over five years). The longevity of restorations depends on many factors, including: materials used, type of restorative procedure, patient parameters, operator variables, and local factors.

## INTRODUCTION

A wide variety of materials are used by dentists in the restoration of teeth. Many factors need to be considered by both the dentist and the patient when choosing the optimal restorative material for each procedure, with the longevity of that particular restorative material being one of the most important.<sup>1,2</sup>

Restoration success is the demonstrated ability of a restoration to perform as expected, whereas the length of time

## ACRONYMS

<b>CEREC:</b>	Chairside Economical Restoration of Esthetic Ceramics
<b>FPD:</b>	Fixed partial dentures
<b>GIC's:</b>	Glass ionomer cements
<b>PFM:</b>	Porcelain fused to metal
<b>YST:</b>	Yttrium-stabilized tetragonal type

that a restoration survives (survival rate), is often used as a measure of clinical performance. Replacing failed restorations constitutes about 60% of all operative procedures carried out by dentists, with estimated annual costs of around \$5 billion in the USA alone.<sup>1</sup> Restorations have a limited lifespan and once a tooth is restored, a “restorative cycle” commences, where the restoration will likely be replaced many times throughout the lifetime of the patient.<sup>3</sup> Dentists are obliged to inform their patients about the survival rates of different materials and restorative procedures. This will allow the patients to make informed decisions regarding their treatment options. The United States Public Health Service (USPHS) criteria have been used most widely to determine the clinical performance of restorations. This requires two independent examiners and uses a grading system based on a number of observations (eg. retention, colour match, secondary caries, etc.). For each observation there is a grading from Alpha (perfect), Bravo (less perfect), to Charlie (complete failure).<sup>1</sup> The majority of the articles reviewed in this paper used these criteria in their evaluation, with the main focus being on survival rates.

## DETERMINANTS OF RESTORATION LONGEVITY

A wide variety of both patient and clinician variables will influence the longevity of restorations.<sup>4</sup> These include:

**Caries index**, where a high index is often associated with a low restoration longevity, usually due to recurrent caries.<sup>5</sup>

**Restoration size**, with larger restorations having greater failure rates due to their greater surface area, making them more susceptible to recurrent caries, fracture, and restoration failures.<sup>5</sup>

**Tooth position**, with molars having lower restoration survival rates than anterior teeth.<sup>5</sup> This relates to restorations being larger on posterior teeth and sustaining greater occlusal forces, affecting their longevity.

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**Clinician variables:** more experienced clinicians have higher restoration survival rates.

Patient parameters may also play a role. Studies found that those who regularly change dentists had their restorations replaced more frequently, while restoration failures are highest among older patients and lowest in the 4-18 year age group. This may purely be due to older patients having older restorations, however, caries incidence is also higher in the elderly due to changes in their stomatognathic system, impaired motor function, and reduced salivary flow rates, amongst others.<sup>5</sup>

### HOW LONG SHOULD RESTORATIONS LAST?

A literature search was undertaken using Pubmed in the identification of relevant articles published from 1974 up to and including 2014. The following keywords were used: longevity, restorations, prosthodontics, crowns, all ceramic, zirconia, CAD/CAM, amalgam, composite, lifespan, survival. Twenty two articles have been included in this review, which covers both direct and indirect restorative materials as well as different manufacturing techniques.

### DIRECT RESTORATIONS

#### Amalgam

This is still one of the most commonly used restorative materials in posterior teeth in some countries. Its use is however declining due to higher aesthetic demands of patients and their concerns over mercury toxicity.<sup>6</sup> It has a unique ability to seal itself over time by a phenomenon known as “creep”,<sup>7</sup> which has been defined as “the deformation of a metal under a load that is below its proportional limit”.<sup>8</sup> Dental amalgams have been shown to “creep” as a consequence of low-frequency cyclic stresses resulting from mastication and from thermal changes during ingestion of hot and cold food. The material expands with internal corrosion and phase changes, which will fill in the microscopic space at the tooth-amalgam interfaces. The median survival time of amalgam has been estimated to be 22.5 years,<sup>2</sup> with some studies showing annual failure rates of 3%.<sup>4</sup>

#### Composite resin

Early composite resin materials showed failure rates as high as 50% after 10 years.<sup>2</sup> This has drastically improved with the introduction of newer products. These materials can currently be classified as nanofilled, microfilled, or micro/nanohybrid materials with filler quantities varying from 42-55%. Of these, the hybrid composites performed the best with annual failure rates of 1.5-2%, most often as a result of restoration fracture.<sup>9</sup> The major drawbacks of these materials are polymerization shrinkage and polymerization stress. These have the potential to initiate failure at the composite-tooth interface which will result in post-operative sensitivity and the opening of pre-existing enamel microcracks. Newer low stress flowable base materials can overcome some of these problems by reducing the amount of stress generated during polymerization (1.4 MPa compared with 4 MPa for other flowable composites).<sup>10</sup> Such restorations should be followed up periodically for early detection of problems as once failures are initiated there is usually a rapid progression. The placement of glass ionomer cement liners under composites further improved their success rates and is now regarded as a “gold standard” procedure especially in posterior teeth. These cements resist caries formation in the adjacent tooth structure by maintaining the pH at levels above

those required for demineralization to occur.<sup>11</sup> Current approaches have seen the introduction of new nanocomposite materials which release fluoride (F<sup>-</sup>), calcium (Ca<sup>2+</sup>), and phosphate (PO<sub>4</sub>) ions. These calcium and phosphate ions combine to form hydroxyapatite [Ca<sub>10</sub>(PO<sub>4</sub>)<sub>6</sub>(OH)<sub>2</sub>], thus strengthening the tooth and combating secondary caries.<sup>12</sup> More studies and further development of these new materials is however needed.

### GLASS IONOMER CEMENTS (GIC'S)

As mentioned, GIC's make an excellent dentine replacement as a lining or base when managing dentinal caries but lack the physical properties needed to be used alone for posterior restorations.<sup>2</sup> In addition, they are more readily lost interproximally where reduced saliva flow leads to sustained low pH levels. Improved saliva flow on other tooth surfaces helps restore the resting pH levels.<sup>11</sup> These materials are most effective buffers in acidic environments and are also excellent luting agents. Their primary use is for restoring Class V cavities, primary teeth, and in the ART technique (atraumatic restorative treatment). In primary teeth GIC's have a 93-98% survival (over the longevity span of the tooth), and a median survival of 30-42 months in permanent teeth. Their annual failure rate when used alone as a restorative material is estimated to be 7%.<sup>4</sup>

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## INDIRECT RESTORATIONS

### Gold crowns and inlays

These are considered the “gold standard” against which all other restorations are measured in terms of longevity. The most common biological reason for their failure is secondary caries, with retention loss being the most common technical cause of default. Studies have shown survival rates to range from 96% over 10 years, 87% over 20 years, to 74% over 30 years<sup>2</sup> with a mean failure rate of 1.4% in the posterior permanent dentition.<sup>4</sup>

### Porcelain fused to metal (PFM) crowns

These restorations have been reported to have a 97% 10 year survival rate.<sup>2</sup> The majority of failures (65%) occur in the anterior region (traumatic zone), and have been attributed to eccentric chewing forces, iatrogenic factors, accidents, and inadvertent contact with instruments during surgical operations.<sup>13</sup>

## ALL CERAMIC CROWNS

Many different types of materials are available for all-ceramic restorations. These can be chosen depending on the properties required for a particular clinical situation (such as aesthetic concerns versus the need for strength).<sup>2</sup>

The lifetime of these materials depends on the presence of incidental cracks and their propagation under intra-oral conditions.<sup>14</sup> There are substantial differences in material properties of the different ceramics, and thus they should be considered separately.

### Heat pressed, reinforced ceramics

Leucite-reinforced (eg. IPS Empress I) is reported to have a 99% survival rate after 3.5 years, and a 95% survival after 11 years, with better success reported for anterior restorations.<sup>2</sup> The IPS EMax system is comprised of lithium disilicate ( $\text{Li}_2\text{O}_2\text{SiO}_2$ ) glass ceramic and zirconium dioxide ( $\text{ZrO}_2$ ) materials which are suitable for pressing, but can also be used with the CAD/CAM technologies. This is a highly durable, very strong (360-400MPa flexural strength) ceramic which can overcome some of the problems encountered with the chipping off of porcelain which is commonly encountered in zirconia restorations. Studies have shown their survival rates to be promising, with systematic reviews showing these to be in the region of 96% after five years.<sup>15</sup>

### Slip-cast glass-infiltrated ceramics

These include magnesia, alumina, and zirconia infiltrated variants, with some studies showing survival rates of 92-100% over five years for the magnesia and alumina variants.<sup>2</sup>

### Metal oxide ceramics

These materials usually contain alumina or zirconia which confer a toughness and superior fracture resistance but also inferior aesthetics due to the inherent opacity found in the high-density metal oxide crystals. Clinical studies have shown Procera Alumina crowns to have success rates of 98% over 5 years, and 94% over 10 years.<sup>2</sup> Zirconia has been referred to as “ceramic steel” because of its superior material properties. It is a crystalline dioxide of zirconium, with mechanical properties similar to those of metals and a colour similar to that of teeth. Zirconia crystals are organized into three different patterns: monoclinic, cubic, and

tetragonal. Zirconia ceramics used in dentistry are of the Yttrium-stabilized tetragonal type (YST), which offer excellent mechanical performance, strength, and fracture resistance.<sup>16</sup> This is possible by the “phase transformation effect” that these materials undergo (tension induced tetragonal-to-monoclinic phase transformation).<sup>14</sup> The net result is a volumetric expansion which compresses cracks to prevent propagation and enhances toughness to resist fractures. Cracking and crazing of the veneering porcelain is of major concern with some studies reporting this problem in as many as 50% of cases after only two years.<sup>2</sup> This is the result of chewing forces being exerted on a very weak 90MPa feldspathic veneering porcelain, with the underlying 1000MPa zirconia substructure remaining intact, leading to ultimate failure of the restoration. Such chipping can also be attributed to rapid cooling protocols during fabrication when firing the veneering feldspathic porcelain onto the zirconia substructure.<sup>14</sup> This can be overcome to some extent by ensuring slower cooling when the final restoration is removed from the furnace.<sup>14</sup> These restorations have survival rates of 96% after two years, and 94% after four years,<sup>2</sup> but longer term clinical studies are still needed.

## CERAMIC INLAYS AND ONLAYS

IPS-Empress inlays and onlays have been shown to have survival rates of 96% after 4.5 years, and 91% after seven years.<sup>2</sup> With the introduction of CAD/CAM systems into dentistry, in particular the CEREC (Chairside Economical Restoration of Esthetic Ceramics) system, clinicians are now able to use composite resin and ceramic materials to fabricate indirect restorations.<sup>17</sup> The CEREC 1 system was mainly used for chairside fabrication of inlays and onlays with long-term studies showing adequate survival rates of 97% over five years, and 90% over 10 years.<sup>2</sup> The main reasons for failure of these restorations were the result of ceramic fracture (feldspathic porcelain), followed by fractures to the underlying supporting tooth. With advances in technology, the CEREC 2 system was capable of producing inlays, onlays, full and partial crowns with survival rates of 87% over seven years. The current CEREC 3 system will manufacture veneers, short bridges, and implant abutments, with survival rates for these being 95-97% over five years.<sup>18</sup>

## FIXED PARTIAL DENTURES (FPD'S / BRIDGES)

These can be divided into PFM and all ceramic. Studies have shown survival rates to be 92% over 10 years, and 75% over 15 years for the PFM type, 93% survival rates over five years for zirconia, and 89% survival rates over five years for all ceramic FPD's. The sharp decline in survival rates after 10 years (PFM) can be attributed to material fatigue (of the restoration or luting cements), recurrent caries, or retention loss. FPD's on implants have 87% 10-year survival rates.<sup>2</sup>

## RESIN BONDED FIXED PARTIAL DENTURES (MARYLAND)

Longevity rates for these types of restorations vary widely, with some studies showing 88% five year survival rates. They are mostly lost due to de-bonding. Those in the anterior regions seem to survive longer than those in the posterior regions. Posterior restorations in the maxilla survive longer than those in the mandible, possibly due to greater masticatory forces being applied to the posterior mandible causing more frequent de-bonding at this site.

When these restorations are re-bonded there are greater failure rates, with 40% failing after their first re-bonding and 60% failing after second re-bonding respectively. Inappropriate case selection, and design flaws will not be corrected by re-bonding these types of restorations, which can explain their high failure rates.<sup>2</sup>

## ENDODONTICALLY TREATED TEETH

When restoring endodontically treated teeth, the use of the sandwich technique, where a glass ionomer base is covered with overlying composite resin, is the preferred method for minimizing coronal leakage.<sup>19</sup> When there is inadequate tooth structure remaining, cast post and core restorations have been found to have success rates of 90% over 10 years.<sup>20</sup> If pre-fabricated posts need to be used, fibre-reinforced posts offer better long-term success compared with metal posts, as these tend to cause more root fractures due to their higher modulus of elasticity compared with dentine.<sup>21</sup> Sealer selection is also important with AH-26 (epoxy sealer) offering better resistance to leakage than ZOE (zinc oxide eugenol) based sealers.<sup>19</sup> Endodontically treated teeth can have survival rates of 97% over 5-8 years if adequately restored.<sup>22</sup>

## CONCLUSION

The longevity of restorations is dependent on a multitude of factors making it difficult to compare success rates. Based on current findings, we can, however, convey evidence-based information to our patients regarding anticipated restoration survival rates. It is essential to establish effective communication with our patients so that they can make informed decisions regarding their treatment.

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