MASTEROPPGAVE

Clinical Performance of Empress Reconstructions in a University Clinic

A retrospective study

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Table of contents

Introduction

Ceramics have been used worldwide for thousands of years. Today they have a very broad range of use, e.g. sanitary products, electrical insulators, tiles, spark plugs, parts for turbo charged engines and medical joint prosthesis. Ceramics are also used in the discipline of dentistry, and they are well known for their excellent aesthetics. They are strong and hard, however at the same time they are brittle materials, which in the very beginning restricted their use to the frontal dental segment due to the fracture risk in the premolar and molar regions. Intensive development, and increased knowledge of full ceramics and adhesive bonding techniques, has brought upon a distinct increase in the use of full dental ceramics, both small and larger constructions, in the whole dental arch [1, page 6].

This assignment consists of two sections; the first will cover the history of ceramics in general and the history of dental ceramics with a focus on the full dental ceramics. The second section is a clinical study where the quality of full dental ceramic crowns, made by dental students in Tromsø over the last three years, will be measured.

What are ceramics?

A ceramic is an inorganic, non-metallic solid resulting from the processes of heating and subsequent cooling. Ceramic materials may have a crystalline or partly crystalline structure, or may be amorphous (e.g. glass). Because most common ceramics are crystalline, the definition of ceramic is often restricted to inorganic crystalline materials, as opposed to the non-crystalline glasses [2].

The word ceramic is derived from the Greek word keramikos, "of pottery" or "for pottery", from keramos, "potter's clay, tile, pottery" which is said to come from the Indo-European word “cheros”, meaning heat [2].

The history of ceramics

The production of ceramics is one of the most ancient human industries. Pot making, for instance, is one of humankind’s first inventions, and because of the durability of the ceramic products they are some of the best records of human cultural beginnings [3]. The industry was born when it was discovered that clay could be excavated and formed into objects by first mixing it with water and, secondly, after forming the objects, fired. There are records of ceramics as far back as 24,000 BC. Animal and human figures were made out of clay and fired in kilns dug into the ground. Almost 10,000 years later, as settled communities were established, tiles were produced in Mesopotamia and in India [4]. The earliest known functional pottery for storing water and food dates back to around 10,000 BC in Asia and 6,000 BC in the Middle East.

Because of the arduousness of firing to sufficiently high temperatures, in order to produce more durable ware, it is likely that the very earliest ceramics were too fragile to have survived, or maybe too scarce to have been discovered by archeologists [5].

At the very beginning pots were made by hand with rolled coils, sometimes using baskets as moulds, and fired on open fires. Over time the potter’s wheel was invented, the firing was made more fuel-efficient and better-controlled using ovens, glazes were also developed. Individual culture’s ceramic traditions have been significantly influenced by the technical solutions available to them. For example, the classical Roman potters only mastered low temperature firing and had not developed glazing. Therefore, these Roman pots are technically less developed than the glazed ceramics made in China at the same time [6].

A development of ceramics is porcelain. This can be defined as a dense, white and often half transparent ceramic material that is made through the process of sintering. Porcelain, as described here, was first produced during the Tang dynasty in China between AD 600- 900.

This used a unique combination of ingredients; quartz, feldspar and mica. The technique of making porcelain only arrived in Europe during the beginning of the 1700s [1, page 7]

The development of dental ceramics

The availability of dental ceramics has given the profession further options in which material to use when planning a patient's treatment. However these new materials have also increased complexity. This is due to the greater need for detailed knowledge of these materials and how they should be managed within the clinic [1, page 6]

Dental ceramics have only existed for a relatively short period of time. In the late 1700s Duchateau, a French chemist, together with the dentist Dubois de Chemant, developed the concept of using porcelain as a dental reconstructive material. Porcelain was then introduced as a material to make denture teeth, but at that time there was no effective way to attach individual teeth to a denture base material. It was not until the invention of vulcanized rubber in 1839 that porcelain denture teeth was successfully used in a denture base.

During the 1800s, attempts were made to produce inlays and single crowns, but these were generally not successful. At the beginning of the 1900s Dr. Charles Land described the basic principles for single full-ceramic crowns by using a platinum foil matrix and high fusing feldspar porcelain. These early crowns showed excellent aesthetics, but sadly had a high rate of failures because of their low flexural strength [1, page 7; 7, page 660-663].

Significant progress was made in the 1960s to the bonding of feldspar porcelains with a metal core. The first was the process that allowed systematic control of sintering temperature and the porcelain's thermal expansion coefficient. The second was the production of alloys that could be chemically bonded to, and were thermally compatible with, feldspar porcelains. Since then, with their excellent aesthetic performance and clinical endurance, metal-ceramic crowns have been used with great success.

The research of McLean and Hughes [8] paved the way of full- ceramic crowns reinforced with an aluminous core. Already in 1965 they reported significant improvement in fracture resistance of porcelain crowns that were reinforced with a ceramic core containing between 40 and 50% Al_2O_3. As today, because of aluminous porcelains opaque appearance, a thin outer layer of feldspar porcelain was required to achieve satisfactory aesthetics. Unfortunately these new ceramic crowns showed a relatively high fracture rate when used for molar crowns. Therefore their excellent aesthetics have been exploited predominately as an alternative material in restoration of anterior maxillary crowns.

Glass ceramics were developed by Grossman and Adair in 1968 [7, page 660-663] and further advanced in the 1990s via press able glass-ceramic (IPS Empress) that was reinforced with leucite crystals. In the late 1990s a more fracture resistant press able glass-ceramic (IPS Empress 2) was introduced [7, p 660-663].

Acid-etch technique was introduced by Rochette in 1973 [9] and bonded ceramics in 1983 by Simonsen and Calamia [10].

The prohibition on use of amalgam and an increased demand for tooth-coloured restorations has seen an increase in the demand for ceramics and polymer-based restorations. The clinical potential for full-ceramics has never been greater [7, page 660-663]. Today's computer-aided design and computer- aided manufacturing (CAD-CAM) makes it possible to scan prepared teeth and then mill prosthesis from a block of ceramic.

There are a variety of different types of full dental ceramics on the market today, all with different kinds of properties when it comes to strength and aesthetics. An overview of the most commonly used full-ceramics in the Nordic countries is listed in table 1.

Table 1. Overview of the most commonly used full ceramics in the Nordic countries (7, page 689; 11, page 325)

Product	Recording method	Processing method	Material	Area of use
Procera®, Nobel Biocare	Mechanical contact on the model	Sintering on computermanipulated model	Aluminumoxid/ Zirconiumoxid	Crowns, 3-unit FPD*
Cerec 3D®, Sirona	Optical registration of tooth or cast model	Milling of computermanifactured model, later glassinfiltration	Aluminum/ Zirconium-reinforced ceramic	Crowns, 3-unit FPD*
Denzir®, CAD. Esthetics	Laser-scanning of cast model	Milling of computermanifactured model	Densely sintered zirconiumoxide	Crowns, 3-8-unit FPD*
DC Zircon®, DCS Dental	Laser-scanning of cast model	Milling of preparation the way it is registrated (imprint, computermanifactured model)	Densely sintered zirconiumoxide	Crowns, 3-8- unit FPD*
Everest®, KaVo	Optical registration of cast modell & wax model	Milling of enlarged model on partly sintered zirconiumoxide	Non-shrinkable zirconiumoxide	Crowns, 3-unit FPD*
Lava®, 3M ESPE	Photo-optical registration of cast model & index	Milling of enlarged model on partly sintered zirconiumoxide	Zirconiumoxide	Crowns, 3-4-unit FPD*
Celay®,Vident	Model of restoration in wax	Copy-milling, later glassinfiltration	Aluminumreinforced ceramics	Crowns, 3-unit FPD*
			Zirconiumreinforced Cermaics	Crowns, 3-4-unit FPD*
IPS Empress®	Model fabricated in wax on cast model	Hot- pressed (not cad/cam)	Leucite reinforced glass ceramics	Crowns/Veneers/Onlays
IPS Empress 2®	Model fabricated in wax on cast model	Hot- pressed (not cad/cam)	Lithia disilicate reinforced glass ceramics	Crowns/Veneers/Onlays, 3-unit FPD* extending to 2. premolar
IPS e.max®		Hot- pressed and CAD/CAM	Lithium disilicate and/or Zirconium oxide reinforced glass ceramics	Crowns/Veneers/Onlays 4-unit posterior FPD*

Full dental ceramics and their qualities

SILICATE CERAMICS

These are sintered ceramics that consist of a small crystalline element in addition to the main component, SiO_2. Thus these ceramics are characterized by an amorphous structure.

Indications

- Dental porcelain that is fused to a ceramic or metal core fall into this classification. These restorations can be used on all teeth, including the buccal segment. The function of the dental porcelain in these restorations is purely aesthetic.

Contraindications

- Silicate ceramics are not suitable for use as a core for full ceramic crowns or fixed partial dentures.

Cementation

- Silicate ceramics require an adhesive technique with light, chemical or dual curing polymer-cement, depending on the type and anatomy of the restoration to be cemented. (e.g. Panavia, Variolink, Multilink).

OXIDE CERAMICS

Oxide ceramics consist of a crystalline element with or without a small glass structure. Their principal function is to increase the strength of the ceramic construction. The high amount of crystals gives oxide ceramics an opaque appearance, so to achieve excellent aesthetics dental porcelain is fused to a core of oxide ceramic.

Indications

- Particularly suitable when there is a demand for high strength, good aesthetics and a restoration without any metal.

Contraindications

- Currently there are no absolute contraindications, provided that sufficient dimensions are created after preparation and that the dental porcelain is well supported by the oxide ceramic core.

Cementation

- With their high strength, oxide ceramics are suitable for classical cementation technique using Phosphate cement or Glass ionomer cement.

NON-OXIDE CERAMICS

Non-oxide ceramics include carbides and nitrides, amongst others. These ceramics are, for various reasons, seen as impractical for use in dentistry.

GLASS CERAMICS

Glass ceramics are usually made through a hot-pressing process. Initially the desired shape is formed in glass, then a controlled crystallization of the glass is induced by heat treatment. The resulting ceramic consists of a glass matrix and at least one crystalline element. In comparison to the silicate ceramics there is a greater quantity of small-size crystals and these are more evenly distributed within the glass matrix. This increases the strength of glass ceramics. Glass ceramics are not as strong as oxide ceramics, however their slightly translucent appearance means excellent aesthetics can be achieved.

Indications

- In general glass ceramics are suitable for making veneers, onlays and anterior crowns. Leucite reinforced glass ceramics are suitable for both anterior and posterior crowns (e.g. IPS Empress, IPS Empress Esthetic).
- Lithia reinforced glass ceramics are also suitable for premolar fixed partial denture (e.g. IPS Empress 2, e.max).

Contraindications

- Without Leucite or Lithia reinforcement, glass ceramics have insufficient strength for posterior restorations.

Cementation

Glass ceramics require an adhesive technique with light, chemical or dual curing polymer-cement, depending on the type and anatomy of the restoration to be cemented. (e.g. Panavia, Variolink, Multilink).

IPS EMPRESS

Today, sintering methods and manual or computer aided milling techniques, along with hot-pressed ceramics, are widely used. The IPS Empress system (Ivoclar Vivadent AG, Schaan, Liechtenstein) was introduced by Ivoclar Vivadent in 1990. This system is comprised of a leucite-reinforced glass-ceramic, which is pressed into the desired shape according to the lost wax principle. It is suitable for fabricating single restorations, such as inlays, onlays, veneers and partial and full crowns. The pressable, leucite-reinforced ceramic IPS Empress is an all-ceramic material with one of the longest clinical track records [12]. It has been on the market for more than 15 years; in 2004, its name was changed to IPS Empress Esthetic.

Preparation technique, full dental ceramics

The preparation requirement is similar to that for metal-ceramic full-coverage restorations. The tooth should be prepared, with a chamfer diamond, aiming for 1.3 mm of axial reduction and 1.5 mm to 2.0 mm for incisal or occlusal reduction (Figure 1-4). The margin design is of shoulder configuration with a rounded axial-gingival line (=chamfer design). The shoulder margin/chamfer design provides the strength and most accurate marginal fit.

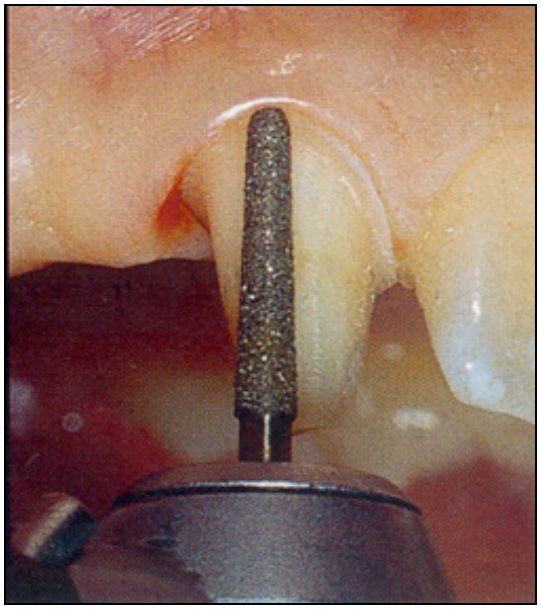

Figure 1. Preparation with a round-ended diamond.

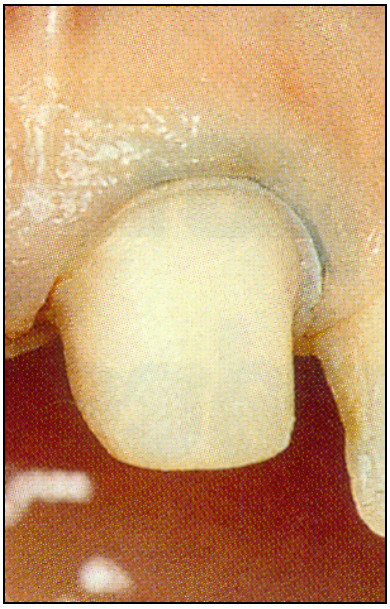

Figure 2. Chamfer preparation

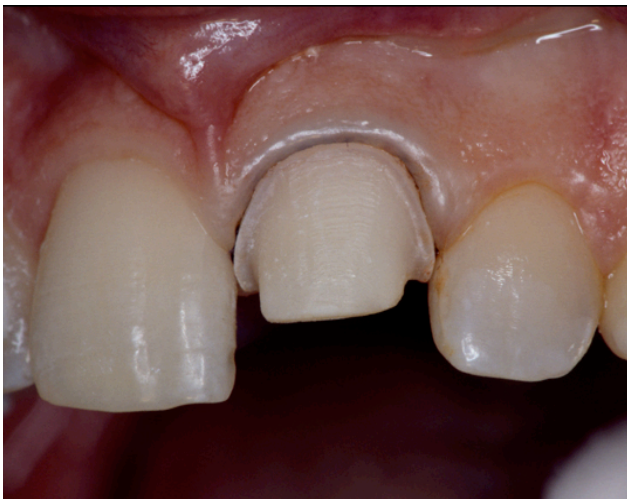

Figure 3. Chamfer preparation 21.

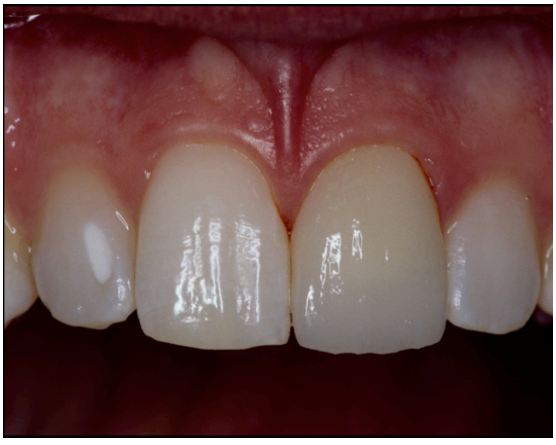

Figure 4. IPS Empress crown 21.

(Photos: L. Pohl)

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A retrospective study

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Bentinck Whatley E, Järvinen Larssen A. *Clinical Performance of Empress Reconstructions in an University Clinic. A retrospective study.*

Abstract

Objective: To retrospectively evaluate empress crowns/onlays placed in patients treated by dentistry students at the University clinic in Tromsø.
Material and methods: A total of 37 empress restorations placed in 26 patients were evaluated according to the California Dental Association´s (CDA) quality evaluation system. All of the reconstructions were luted with resin composite cement. The mean and median age of the restorations was 13.8 and 11 months respectively.
Results: All of the 26 patients were satisfied with the treatment process but two patients had complains concerning functional outcome of the treatment. The survival rate according to the Kaplan Meier method was 94.8 %. Based on the CDA criteria, in the category 'Anatomic form', 84 % of the reconstructions were given the score SOCO (= restoration is slightly over-contoured). In the category 'Color' the CDA code SMM (= mismatch between restoration and tooth) was registered in 54% of the reconstructions. In the category 'Surface', 56 % received the code SRO (= surface of restoration is slightly rough or pitted).
Conclusions: The majority of the patients were very satisfied with the overall treatment received at the university clinic. The relatively high number of restorations reported as slightly over- contoured might indicate the need for improvement upon the preparation procedures of empress reconstructions. A longer observation period and more restorations are needed to draw any firm long- term conclusions for the overall quality of empress restorations made by dentistry students.

Key words: Clinical study, all-ceramic crowns, glass ceramics, survival rate

Introduction

In prosthetic dentistry there is a tendency towards replacing metal-based restorations with all-ceramic alternatives. Good clinical survival rates have been reported with single crowns made of different ceramic materials (lithium di-silicate, leucite, aluminum oxide) and thus the use has increased [1]. Conventional dental ceramics reveal several clinical shortcomings including poor marginal fit, sintering shrinkage, difficulty in polishing, bulk fracture, excessive wear of opposing teeth [2, 3, 4, 5], which are important factors when all-ceramic crowns are selected for clinical applications [6]. These shortcomings have earlier limited the indications for dental ceramics and therefore clinicians have been skeptical of new all-ceramic systems for a good reason, the clinical performance of many of the ceramic systems have fallen far short regarding the manufacturers' claims about their products [7, 8, 9].

During the past decades restorative dentistry have been facing new challenges in adopting emerging technologies related to dental materials and in an increased demand for esthetic nonmetallic, highly biocompatible dental restorative materials. This has resulted in the introduction of improved ceramic formulations and development of all-ceramic materials, used for individual crowns, veneers, inlays, onlays, fixed partial dentures, and implant restorations [7]. At present, most all-ceramic systems fall into 3 categories: alumina-based and zirconia-based core materials and cast able or press able glass matrix ceramics. The IPS-Empress system belongs in the latter category. The IPS-Empress system was developed at the University of Zurich, Switzerland, in 1983 and was presented to the profession in 1990 by Ivoclar Vivadent. It has been on the market for nearly 20 years and in 2004 its name was changed to IPS Empress Esthetic.

The introduction of new bonding procedures, new luting techniques and new cements have helped to overcome some of the challenges related to the cementation of all-ceramic reconstructions and therefore increased the acceptance of these ceramic systems. While the

resin cementation system offers some great clinical advantages such as outstanding esthetics, reduced microleakage by sealing of margins [10] and strengthening of the ceramic crown, it does also have some disadvantages. First, margins can be placed only minimally subgingival otherwise sulcular fluids will contaminate the bonding surfaces. Second, the technical procedures and moisture control are much more demanding compared to conventional cementation procedures. The longevity of the Empress restoration may seriously be compromised if the dentist fails to have moisture control during the adhesive cementation process since resin cementation is considered a technique-sensitive procedure.

Although the Empress system was introduced in the early 1990s, there are few studies dealing with the clinical performance of Empress all-ceramic crowns/onlays, whereas numerous in vitro studies have dealt with the resistance of all-ceramic crowns to flexural stress. In vitro investigations, however, are commonly incapable of addressing all clinically relevant criteria. In vivo evaluation has been the ultimate basis for establishing criteria for acceptable crowns [2]. Thus, clinical studies are needed to evaluate the performance of restorative materials.

The purpose of the study was to retrospectively evaluate the clinical performance of Empress all-ceramic crowns/onlays placed in patients who had been treated by the dental students at the University clinic in Tromsø.

Materials & Methods

Study Group

In order to identify all the patients that had received Empress ceramic restorations, the authors searched the invoice archive from when dental students started to treat patients in Tromsø (February 2008). In total 33 patients had received 48 full ceramic crowns and onlays during this time at the student clinic. Four of these were Procera crowns (one crown in four patients), and thus have been excluded from this study. Moreover, the authors did not get hold of one

patient (= one crown). One Empress crown that had fractured and replaced with a metal ceramic crown was also excluded from the clinical part of the study.

Of the 27 patients invited one declined to take part in the study. The remaining 26 patients provided a total of 37 Empress restorations for investigation. All 26 patients attended the clinical examination, constituting 14 females and 12 males. The mean and median age of the patients was 50.6 and 52 years, respectively.

Data Collection

Information regarding the luting agents used, and whether the crowns were luted on endodontically treated teeth or on teeth judged to be vital, was obtained from patient records. In addition, information regarding any adjustment, endodontic treatment, re-cementation, fractures, or postoperative inconvenience was obtained from patient records or from discussion with the patients. Since no plaster models were kept after cementation of the reconstructions the individual tooth preparations could not be evaluated regarding design and amount of tooth substance removed.

The survey comprised clinical examination in order to assess the CDA score. Furthermore, symptoms reported by patients, such as postoperative inconveniences were registered according to a routine protocol [Appendix I; variables marked * were registered]. The study was conducted at the student dental clinic in Tromsø using standardized equipment and lighting condition. All participants were given fixed appointment to attend the clinic for the examination and interview. Furthermore, all patients were asked about their subjective opinion of the treatment that they had received.

Of the 37 restorations, 27 were full crowns and ten were onlays. One of the full crowns, and two of the onlays were placed on endodontically treated teeth. The remaining teeth were judged to have a vital pulp. The restorations were manufactured in three different commercial dental laboratories in Tromsø. Two different luting agents were used for cementation of the

restorations, Panavia F 2.0 and Variolink (Table 1). There were four crowns and four onlays placed on molar teeth, seven crowns and six onlays on premolar teeth and finally16 crowns placed on incisor teeth. A clinical photo of an upper right lateral Empress crown (no. 35) can be seen in Figure 1.

California Dental Association's (CDA) quality evaluation system

The full-ceramic Empress crowns, onlays and veneers were examined in accordance with the California Dental Association's (CDA) quality evaluation system [11]. Two evaluators examined the crowns 'Color, 'Surface', 'Anatomic form' and 'Margin integrity'. The evaluators were trained in the use of this evaluation system. The calibration between the examiners prior to the clinical examinations was conducted under the supervision of their tutor. The calibration took place on two occasions, using the CDA categories and terms. The first session took place at the end of the 8th semester (four crowns) and the second at the beginning of the 9th semester (five crowns). Nine crowns in total where used for calibration, five of these also participated in the assignment. A brief summary of the CDA rating system used is presented in Table 2.

The evaluators undertook this study as a pair but worked independently of each other. Where there was disagreement in the rating of a given restoration, the evaluators agreed upon a final rating by joint examination.

Calibration – Cohen's Kappa test

The Cohen's Kappa test is used to control the calibration of multiple researchers. This is a measure of association (correlation or reliability) between two assessments of the same subject when the measurements are categorized. Kappa is often used to study the level of agreement between two raters. Each rater classifies each subject, into the given categories. In this case the CDA criteria of 'Color', 'Surface', 'Anatomic form' and 'Margin integrity' were used.

The statistically significant kappa test indicate that one should reject the null hypothesis that the ratings are independent (kappa = 0) and accept the alternative that agreement is better than one would expect at random. Values less than 0.40 indicate low association; values between 0.40 and 0.75 indicate medium association; and values greater than 0.75 indicate high association between the two raters [12].

Normally one would use this test on the total amount of variables in the research. In this assignment the test has been executed on all variables and on each variable individually. This is due to the inter-examiner association in total resulting in a medium kappa value, and the examiners wanted to identify the origin of this.

Statistical methods

The Kaplan-Meier method was used to make a statistical analysis of the fracture rates obtained for the single-tooth reconstructions. It was also used to calculate the survival rate of the single-tooth reconstructions [13].

Literature search

A MEDLINE and PubMed English language peer-reviewed literature search was conducted in February 2010 and January 2011 to identify clinical trials of the performance and longevity of all ceramic restorations made with the IPS-Empress system that had been published between 1992-2010. Studies with a follow-up time of two years or more were included. The search words used were ”Empress”, “clinical” and “crown”. Only studies that dealt with onlays or/and crowns were included. Studies that were published in abstract form only were excluded.

Seven clinical studies were found to have investigated IPS Empress crowns. One study was excluded because it was published only in German [14]. Of the remaining six studies (Table 5), three were prospective trials, two were retrospective and one was a case series [15-20].

Ethical Considerations

Informed consent was sought from all patients, who had the right to reject to participate in the survey and the right to defend his/her integrity. Prior to the examination, the patients received an information leaflet [Appendix II] regarding the purpose of the clinical evaluation. Moreover, the examiner explained the content of the consent form [Appendix III] to the participants before the evaluation was performed.

Results

A total of 27 crowns and 10 onlays placed in 26 patients were clinically evaluated. The mean and median age of the restorations were 13.8 and 11 months, respectively (range: 5 to 29 months).

Survival-rate

The survival rate according to Kaplan Meier method was 94.8 % (Figure 2).

Distribution of fractures

Two Empress crowns (Table 3; no. 6 and no. 37) fractured after 10 months and 1 month in use respectively. A metal ceramic crown and a new Empress crown had replaced these crowns.

Patient's subjective comprehension of the treatment

A total of 24 patients (92.3%) were completely satisfied with the treatment process and the result of that treatment. The remaining two (7.7%) of the 26 patients had complaints. Both were satisfied with the treatment process, but not with the result. One of these patients (3.8%) was still after 8 months experiencing icy, tender pain. The other patient (3.8%) was experiencing phonetic problems in addition to traumatic occlusion to the lower lip. In the latter case retreatment has been planned.

CDA-score

None of the 37 Empress restorations were given top satisfactory score on all four categories according to the CDA criteria**.** 32 % was given the top satisfactory score on three categories, 43 % was given top satisfactory score on two categories and 24 % was given top satisfactory score in only one category.

In the category 'Anatomic form' just above 84 % of the reconstructions were given the score SOCO (= slightly over contoured). In the categories 'Color' and 'Surface' SMM and SRO were registered in 54 % and 56 %, respectively (Table 4). None of the restorations were clinically or aesthetically rated as of poor quality.

Inter-examiner agreement - Cohen's Kappa test

The inter-examiner agreement was 77 % in total. If assessed using the Cohen's Kappa test, on all the categories, the value score was 0.56, indicating a medium association between the examiners. The Kappa test value scores for each category individually were as follows; Colour: 0.41 (medium association), Surface: 0.45 (medium association), Anatomic form: 0.45 (medium association), Margin integrity: 0.89 (high association).

Discussion

The School of Dentistry at the University of Tromsø is a relatively new institution and the authors of this report wanted to evaluate whether the quality of all-ceramic Empress restorations made by Tromsø students were of a satisfactory quality.

The overall survival rate in the present study was 94.8 %. Compared to other studies [15-20] the survival rate is within the same range (Table 5). However, it has to be reminded that due to the low number of reconstructions a couple of fractures, as in this case, will have a great impact on the survival-rate.

None of the included onlay reconstructions in the present study had failed. Naeselius et al. [21] reported in a retrospective study that seven per cent had failed after four years. Though, one has to take into consideration the short follow up time in the present study.

Earlier studies [17, 18, 20] emphasize, due to fracture risk, that some caution should be exercised in restoring posterior teeth. This has not been confirmed in the present study where only two fractures appeared, one in the posterior and one in the anterior region. These crowns (5.2 %) failed because of fractures after only ten months and one month in service respectively. This may indicate that parafunction and/or technique sensitivity is the cause of failure. All new materials that are introduced as an alternative have to be as reliable as metal-ceramic, which is considered as the golden standard with regard to fracture rate. A systematic review by Pjetursson and co-workers [22] revealed that the incidence of metal-ceramic crown lost due to ceramic fractures was 0.4 % after five years.

The majority of the patients were satisfied with the overall treatment. One patient (3.8%) complained about post-cementation sensitivity. Sorensen et al. [17] reported from clinical trials an incidence of 5.6 % tooth sensitivity after cementation. During the years since the article of Sorensen et al., the adhesive technique has undergone considerable development, leaving the expectance of post-cementation sensitivity to be decreased.

None of the reconstructions were given top satisfactory score in all CDA categories. One of the categories stand out; 'Anatomic form', 83 % of the restorations were given the score SOCO. It does not mean that the anatomic form of the reconstructions in this study is of poor quality, but it arises questions regarding the phenomena. Due to the examiners being inexperienced they might have been too strict in their evaluation. Leknius et al. [23] reported from an in vitro study differences among operators with and without clinical experience regarding judgment of crown margins. Hence an evaluation by experienced operators might have given a different result. Furthermore, it might also be that not enough tooth substance was removed during preparation. This being the case indicates that the clinical instructors, and therefore the dental students, are too cautious during preparation, which in turn forces the dental technicians to produce crowns that are over contoured in order to avoid fractures. This could not be evaluated since no plaster models were kept after cementation. No difference between the three laboratories was seen regarding the amount of restorations with SOCO, which indicates that preparation factor, might be the problem.

The code SCR in the category 'Margin integrity' was registered in only one restoration. One could expect that this code would have been used more frequently when rating older reconstructions where the cement has been washed out during time. Even though, one restoration received the code VSF, it was only polished and will be followed up.

The Inter-examiner agreement being relatively low might indicate that the calibration of the examiners was not thorough enough. The examiners short time of clinical experience also has to be taken in consideration. It should be noted that the low number of restorations examined means that only a few disagreements will result in the Cohen`s Kappa score decreasing considerably.

Several high-strength materials have been developed after the introduction of IPS Empress system. Empress 2 (lithium-di-silicate-ceramic) was introduced to the market in 1988. It was

replaced in 2006, by the translucent lithium di-silicate material IPS e.max Press, which allows full-contour restorations to be fabricated, even FPD:s. Prospective clinical studies have reported low fracture rates, between 0 % and 3 % after 5 years [24-27].

Due to a short period of practice, and the low number of patients, it has not been possible to draw any firm long-term conclusions for the overall quality of full-ceramic Empress restorations made by student dentists at the university clinic. This study should therefore be reviewed as a detailed quality control exercise.

Conclusion

- The initial clinical results of IPS Empress Esthetic are encouraging. However, a longer observation period and more restorations are needed to provide a prognosis regarding its long-term clinical behavior.
- The high number of restorations reported as SOCO (= restoration slightly over- contoured) in the category anatomic form might indicate the need for improvement upon the preparation procedures of Empress reconstructions.
- The majority of the patients were very satisfied with the overall treatment, both from a functional and esthetical point of view.

Acknowledgement

We would like to thank all the patients, who voluntarily participated in the study. The authors also greatly appreciate all the help that was given by the dental assistants at the University dental clinic. Finally, we would like to acknowledge our supervisor Dr. Anders Tillberg for valuable help.

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Table 1. Design of ceramic reconstruction, location of root filled teeth and type of cement

FPD no.	Design	Root filled	Cement
1	24 Empress		Panavia F 2.0
2.	25 Empress		Panavia F 2.0
3.	45 Empress		Panavia F 2.0
4.	12 Empress		Variolink
5	46 Empress		Variolink
6.	36 Empress*		Panavia F 2.0
7	42 Empress		Panavia F 2.0
8.	41 Empress		Panavia F 2.0
9.	31 Empress		Panavia F 2.0
10	32 Empress		Panavia F 2.0
11.	21 Empress		Variolink
12.	46 Empress/onlay		Variolink
13.	45 Empress/onlay		Variolink
14.	25 Empress/onlay		Panavia F 2.0
15.	14 Empress		Variolink
16.	15 Empress		Variolink
17.	17 Empress		Panavia F 2.0
18.	22 Empress	x	Variolink
19.	24 Empress/onlay		Variolink
20.	16 Empress		Panavia F 2.0
21.	47 Empress/onlay		Variolink
22.	46 Empress		Variolink
23.	45 Empress/onlay		Variolink
24.	25 Empress/onlay	x	Variolink
25	46 Empress onlay	x	Panavia F 2.0
26.	21 Empress		Variolink
27.	22 Empress		Variolink
28.	21 Empress		Panavia F 2.0
29	22 Empress		Panavia F 2.0
30	11 Empress		Panavia F 2.0
31	15 Empress		Panavia F 2.0
32	25 Empress		Variolink
33	35 Empress/onlay		Panavia F 2.0
34	36 Empress/onlay		Panavia F 2.0
35	12 Empress		Variolink
36	11 Empress		Panavia F 2.0
37	21 Empress*		Panavia F 2.0
38	21 Empress		Panavia F 2.0
39	22 Empress		Panavia F 2.0

* not clinically evaluated

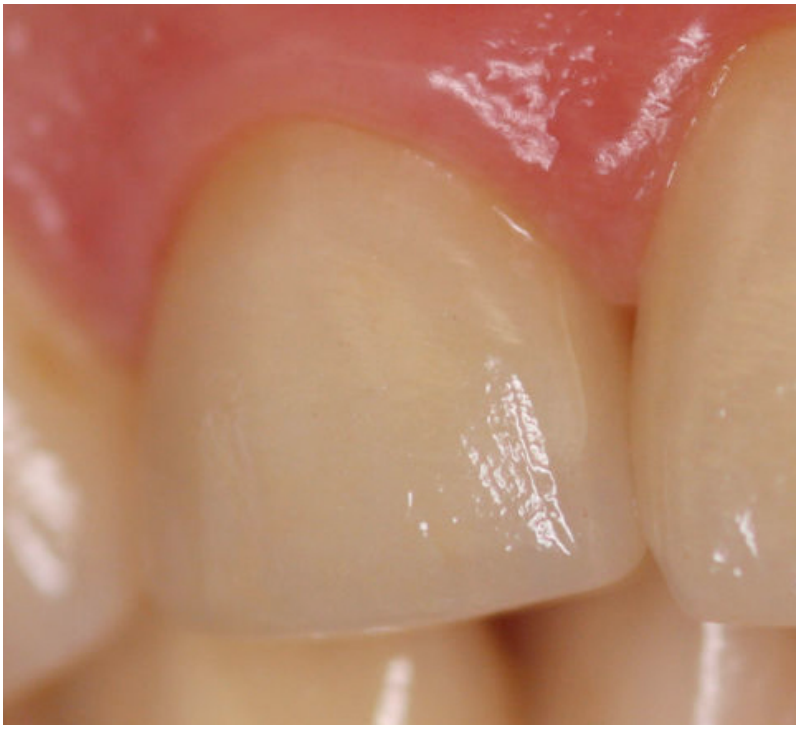

Figure 1. Empress crown on an upper right lateral incisor (no. 35).

Table 2. Criteria for the CDA ratings

RATING	CODE		COLOR
	acceptable	*not acceptable*	
R_0			Absolute perfect
R_1			Small mismatch in color, shade and/or translucency
S	SMM		Mismatch between restoration and tooth structure within the normal range of tooth color, shade and/or translucency
T		TMM	Mismatch between restoration and tooth structure outside the normal range of tooth color, shade and/or translucency
V			Esthetically displeasing color, shade and/or translucency

RATING	CODE		SURFACE
R_0			Absolute perfect
R_1			Surface of restoration is smooth. No irritation of adjacent tissue
S	SRO		Surface of restoration is slightly rough or pitted, can be refinished
T		TPIT	Surface deeply pitted; irregular groves: cannot be refinished
V		VSF	Surface fractured or flaking

RATING	CODE		ANATOMIC FORM
R			Absolute perfect
S	SUCO		Restoration is slightly under-contoured
	SOG		Occlusal contour not continuous with that of cusps and planes
	SOH		Occlusal height reduced locally
	SMR		Marginal edges slightly under-contoured
	SCO		Contact slightly opened
	SFA		Facial flattening
	SLG		Lingual flattening
	SPX		Interproximal cervical area slightly under-contoured
	SOCO		Restoration is slightly over-contoured, but excess material could be removed
T		TUCO	Restoration is under-contoured
		TDE, TDB	Dentin or base is exposed
		TOC	Occlusion is affected
		TCO	Contact is faulty (self-correction is unlikely)
		TPX	Interproximal cervical area under-contoured, tissue damage likely
		TOCO	Restoration is over-contoured. Cannot be adjusted properly
		TOV	There is marginal overhang
V		VMIS	Restoration is missing
		VTO	Traumatic occlusion
		VPN	Restoration causes pain in tooth or adjacent tissue

RATING	CODE		MARGIN INTEGRITY
R_0			No evidence of ditching along the margin
R_1			The explorer docs not stick but feel differences in height
S	SCR		Evidence of ditching along the margin, not extending the DE junction The explorer get sticked in one direction
	SDIS		Discoloration of the margin between the restoration and the tooth structure
T		TMD, TMB	Dentin or base is exposed along the margin
		TPEN	Discoloration has penetrated along the margin of the restorative material in a pulpal direction
V		VMD	Restoration is mobile
		VFR	Restoration is fractured
		VCAR	Caries contiguous with the margin of the restoration
		VTF	Tooth structure is fractured

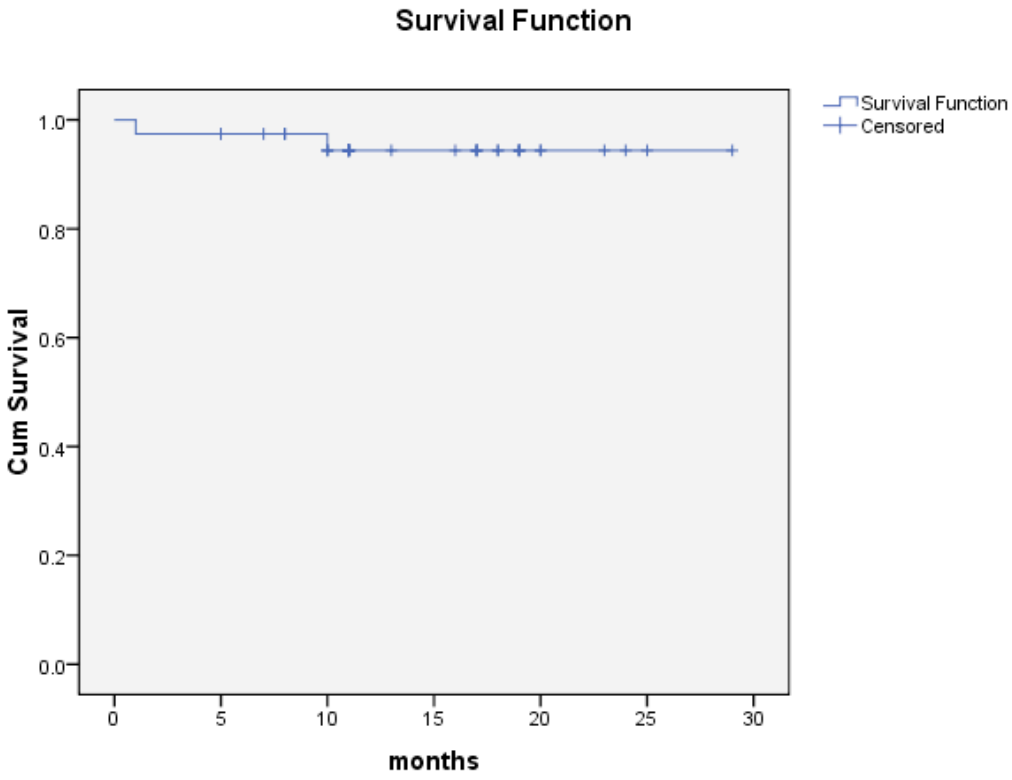

Figure 2. Cumulative survival curve for ceramic reconstructions (n=39).

Table 3. Distribution of fractured full-ceramic reconstructions The times stated refer to the time after luting when the deficiencies were registered (years).

Crown/ onlay no	Design of reconstruction	Luting agents used	Time when the deficiency was registered (months)	Comments
6	36 Empress crown	Panavia F 2.0	10	Fractured. Replaced by a Procera zirconia crown.
37	21 Empress crown	Panavia F 2.0	1	Fractured. Replaced by a new Empress crown
Varia				
28	21 Empress crown	Panavia F 2.0	-	Phonetical problems. Plans to redo the Empress crown

Table 4. Percentages that did not receive an excellent CDA rating* concerning color, surface, anatomic form and margin integrity (n = 37)

	Color	Surface		Anatomic form					Margin integrity	
	SMM	SRO	VSF	SOCO	SUCO	SCO	TOC	VPN	SCR	VFR
n	20	21	1	31	5	1	1	1	1	1
%	54	56	3	84	14	3	3	3	3	3

* SMM = slight mismatch between restoration and tooth structure within normal range of tooth color, shade, and/or translucency; SRO = surface of restoration slightly rough or pitted, can be polished; VSF = Surface is fractured; SUCO = restoration slightly under contoured; SOCO = restoration slightly over contoured; SOH = occlusion is not totally functional; SCO = contact slightly open (may be self-correcting); TOC = Contact is faculty; VPN = Restoration causes unremitting pain in tooth or adjacent tissue,; SCR = visible evidence of slight marginal discrepancy with no evidence of decay; repair can be made or is unnecessary. The explorer got stuck in one direction; VFR = fracture of the restoration;

Table 5. Details of the 6 studies of IPS-Empress crowns

Reference	Type of study	No of patients	No of crowns	Position of tooth	Cement	Follow-up (months)	Survival rate
Fradeani *et al.* (2002)	Retrospective	54	125	93 ant. 32 post.	Variolink	48-132	95% at 11 years
Gamalmaz *et al* (2002)	Prospective	20	37	21 ant 16 post	Variolink	12-41	94.6% at 2 years
Sjögren *et al.* (1999)	Retrospective	29	75 crowns 35 onlays	43 ant. 67 post.	RC cement	42	92% at 3.5 years
Sorensen *et al.* (1998)	Prospective	33	75	47 ant. 28 post.	Variolink	14-42	99% at 3 years
Fradeani *et al.* (1997)	Case series	55	144	101 ant. 43 post.	Vaiolink Zinc phosp.	6-68	95% at 3 years
Lehner *et al* (1997)	Prospective	34	78	41 ant. 37 post.	RC cement	1-24	95% at 2 years

Dual, Variolink (Ivoclar Vivadent, Schaan, Liechtenstein)
Zinc Phosphate (DeTrey/Dentsply, Weybridge, UK

KLINISK UTVÄRDERING AV HELKERAMISKA KRONOR

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Anders Tillberg, TkNN/IKO

***** Patient OPUSnr.: _____

STATUS:

KÄKLEDER - ÖMHET VID PALPATION + RÖRELSE

	REG. 0 (us.)	REG. 1 (1år)	REG. 2 (3år)	REG. 3 (5år)
Käkled lat.				
Käkled post.				

1. Nej, 2. Höger (grad II + III), 3. Vänster (grad II + III), 4. Båda (grad II + III)

TUGGMUSKLER - ÖMHET VID PALPATION

	REG 0 (us.)	REG. 1 (1år)	REG. 2 (3år)	REG. 3 (5år)
Masseter				
Lat. pter.				
Temp. fäste				

1. Nej, 2. Höger (grad II + III), 3. Vänster (grad II + III), 4. Båda (grad II + III)

SLEMHINNOR

* CEMENTERING

TAND	LABORA-TORIUM	UNDERFYLLN./ PELARE	CEMENT	CEMENTERING DATUM	INSLIPNING JUSTERING

* HYPERSENSIBILITET

TAND MTRL	REG 0 (us)	REG 1 (utl)	REG II (1år)	REG III (3år)	REG IV (5år)

0 = ej hypersensibel, 1= < en vecka, 2 = två till tre veckor, 3 = intermittent men upphör ej, 4 = konstant

DATUM FÖR REGISTRERING

*** CDA-REGISTRERING**

TAND	MTRL.	Färg I AL EB	Färg II AL EB	Yta I AL EB	Yta II AL EB

TAND	MTRL	Form I AL EB	Form II AL EB	Marg I AL EB	Marg II AL EB

PLAQUE- OCH BLÖDNINGSREGISTRERING

TAND ANT	YTA ANT	Pl I m d	Pl II m d	Bl I m d	Bl II m d

Plaque 0 = inget, 1 = plaque med sond, 2 = synligt för ögat
Blödning 0 = ingen, 1 = blödning

MARGINALINDEX

TAND ANTAG	YTA ANTAG	REG I m d	REG II m d	REG III m d

0 = > 2 mm över gingivan, 1 = 1 mm över gingivan, 2 = i höjd med gingivan, 3 = subgingivalt

*** KOMPLIKATIONER**

TAND	YTA	DATUM	KOMPLIKAT.	ÅTGÄRD	KOSTNAD

Pasient informasjon

Vi vil invitere deg til å medvirke i en studie som gjennomføres av tannlegeutdanningen - IKO (Institutt for Klinisk Odontologi) ved Universitetet i Tromsø, i forbindelse med at du har fått utført protetisk tannerstatning i form av singelkrone/onlay hos oss. Vi kan gjennom denne studien tilby deg en kvalitetskontroll av nevnte tannerstatning(er) i tillegg til en gratis undersøkelse av resterende tenner.

Tannlegestudiet i Tromsø ble opprettet høsten 2004, og er dermed relativt nytt. De første studentene ble uteksaminert våren 2009. Selv om tannlegestudentene har mye teoretisk forberedelse og klinisk øvelse på plasttenner før man behandler pasienter, så er det viktig at det arbeid som utføres kvalitets vurderes etter en tids funksjon i sitt tenkte miljø, dvs i munnen. Det siste tiåret har det skjedd mye innen feltet tannerstatning. Metall-keramiske erstatninger er fortsatt mest brukt, men helkeramiske tannerstatninger gjør nå sitt inntog og brukes mer og mer på grunn av sin overlegne estetikk i kombinasjon med god styrke. Alle materialer i bruk ved studenttannklinikken har gjennomgått nøye laboratorietekniske og kliniske undersøkelser før de tas i bruk. Men det er også her viktig at, særlig ”nye”, materialer kvalitets vurderes etter en tids funksjon i munnen.

Målet med denne studien er å vurdere kvaliteten på helkeramiske tannerstatninger i form av fullkroner og onlay (partielle kroner) utført av tannlegestudenter ved Universitetet i Tromsø. I og med at de tannerstatninger som er gjort her er av nyere dato, vil studien kun gi en pekepinn på om kvaliteten på arbeidet er tilfredsstillende. Det er derimot en viktig pekepinn! Det vil om noen år kunne bli aktuelt å følge opp studien for ytterligere å vurdere kvaliteten. Du vil da eventuelt kunne bli kontaktet for å delta videre.

Hvis du aksepterer å delta i denne studien vil du bli innkalt til kontroll i løpet av høsten 2010. Du vil gjennomgå en undersøkelse av to tannlegestudenter uavhengig av hverandre. Det vil bli tatt røntgen av dine helkeramiske kroner/onlay og deres pilartenner for bruk i studien. I tillegg vil det tas røntgen av dine resterende tenner for å tilby deg en fullverdig gratis undersøkelse av hele bittet (utføres av en av tannlegestudentene). Undersøkelsene skiller seg ikke i særlig grad fra en vanlig undersøkelse du foretar hos tannlege.

Informasjon om deg, undersøkelser, behandlinger og tannprotetiske erstatninger samles inn og bearbeides i et datasystem. Din identitet kommer ikke til å være kjent for andre enn dine behandlende tannlegestudenter og veiledende tannlege.

Din medvirkning er selvfølgelig frivillig og du kan når som helst avbryte din deltakelse. Dette kommer på ingen måte påvirke din eventuell foresettende behandling ved studenttannklinikken.

For ytterligere informasjon, kontakt:

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SKRIFTLIG TILLATELSE

Studietittel: Survival rate of Empress reconstructions and their qualities according to CDA criteria. A clinical follow-up study

Studiekode:| Empress/UTK2010/EBW/AJL

Studiested: Studenttannklinikken, Universitetet i Tromsø

Jeg (pasient) har lest vedlagt pasientinformasjon og har diskutert studien med stud. Odont. Edwin B. Whatley og/eller stud.odont. Andreas J. Larssen og/eller Dr.odont. Anders Tillberg, og har forstått hensikten med denne studien.

Jeg er villig til å delta i denne studien!

Signatur (pasient) : Dato:

Signatur (stud.odont) : Dato: