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Evaluation of success rate of Zirconia based restorations: A systematic review

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Abstract

Background: Evaluation of the different causes listed in literature for the rate of success of Zirconia based restorations.

Material and Methods: With the help of PRISMA guidelines, this Systematic review was carried out. For a time span of 18 years that is from 2003 to 2020, articles were searched using three electronic data bases which are PubMed, Cochrane Library and ScienDirect. The selected 27 articles which included the *in vivo* as well as the *in vitro* studies presented the performance of zirconia-based prosthetic restorations. The studies also stated the commonest reason for failure which ultimately depicted the rate of success of the fixed dental prosthesis. Due to heterogeneity of gathered information, meta analysis could not be carried out.

Results: Failure of bond between veneer material and zirconia sub-structure could be related to the cause of fracture of veneering porcelain hypothetically.

Conclusions: Mechanical connection and building up of compressive strength due to thermal contraction at the time of cooling after sintering process is the reason for the bond developed amongst the two materials.

Key words: Zirconia based restorations, zirconia failure cause.

Introduction

Esthetics satisfying the contemporary consideration for attractiveness is treated with the help of prosthodontic treatment by traditionally restoring the lost function of speech, chewing and deglutition. Social burden and welfare of the profession maximizes the conditioned necessity of esthetics (1).

The materials of choice for the cases in which esthetics is the key expectation are 'Ceramics' in recent times of which 'yttria-stabilized tetragonal zirconia polycrystals'

(Y-TZP) is the most advanced core ceramic (1). This particular material enhanced high toughness and strength in multiple-unit FPDs.

Even if zirconia-based ceramics being a prime material for fabricating FPDs, its high resistance to fracture could also endure high occlusal loads adding a major advantage. Nonetheless, cohesive fractures of the veneering ceramic is a 'weak link' of the restoration seen as the short-term clinical letdowns of zirconia-based restorations (1).

Material and Methods

-Review Question

Population – *In vivo* as well as *in vitro* studies performed with zirconia based restorations

Intervention – Studies with success rate of anterior and posterior zirconia based restorations as FPDs or single crowns.

Outcome –Overall success rate of the zirconia based restorations

-Literature search

From 2003 to 2020, articles were searched using three electronic data bases which are PubMed , Cochrane Library and Sciencedirect. Articles with full texts that contended the criteria for inclusion were attained. To include all relevant articles and for improving the electronic search, a final manual search was carried out amongst the selected articles to get cross references and citations.

PubMed provided 114 articles and Science direct provided 8 articles and citation search provided 17 articles after the electronic and manual search was done. So far , no systematic review has been published on the current topic. Total 80 articles were excluded and 59 articles were screened. These 59 articles were completely analyzed by the title and abstract leading to selection of only 27 relevant articles which served the criteria for inclusion considered for the systematic review.

Results

-Results of data extraction

By gathering all the data after excluding the duplicates,

full text of these 27 articles was attained lead by thorough screening of the remaining 59 articles. Therefore, for this systematic review 27 articles was the final sample size.

-Results of included studies

No inference has yet touched regarding the attempt to substitute the metal in metal ceramic restorations having ceramics of greater resistance. Its discussion began at the end of the 20th century. In current situations, Zirconium oxide the foremost target of research and trials held clinically. Chemical along with dimensional stability, mechanical resistance, hardness, and modulus of elasticity of the similar demand that of stainless steel are the primary characteristics supporting its usage as a biomaterial.

Chipping of veneers often goes overlooked by the patient and is simply corrected by intraoral polishing or repair inferring that it is an esthetic defect of slight status. This is the reason which leads the rate of survival of zirconia-based fixed dental prostheses and metal ceramic restorations equivalent upto 97 to 99% over a period of 5 years.

The greatest numbers of problems due to the usage of zirconium oxide in prosthetic conducts occur with fixed partial prostheses or fixed bridges. Various studies clinically showed cohesive type of fracture of the veneer material as a major and utmost liability. However, there is a debate as to the rate of occurrence of this mechanical letdown because of variations in the variables evaluated in various studies and the success rate of the prostheses have been calculated. They have been summarized in Table 1-1 cont.-1.

Table 1: Success rate of prostheses calculated.

Author	Type of Study	Follow up period	Number of restorations	Quantity and Type of Difficulty	Success rate
Pospiech (2)	Prospective	24 months follow up time	38 (36 patients) Fixed partial prosthesis (FPP)	Chipping seen in 2 prostheses (5.2%)	95.8%
Bornemann (3)	Prospective	18 months follow up time	59 that is 46 patients in which FPP. 44 number of 3-piece and 15 number of 4-piece	Chipping seen in 2 prostheses (3.38%)	96%
Suárez (4)	Prospective	18 months follow up time	18 (16 patients) FPP (3-piece)	Endodontically treated post with root fracture 0 x chipping (0%)	94.5%
Vult von Steyern (5)	Prospective	24 months follow up time	20 (18 patients) FPP (3-5-piece)	Chipping seen in 5 prostheses (15%)	85%
Raigrodski (6)	Prospective	31 months follow up time	20 (16 patients) FPP (3-piece)	Endodontic treatment of single tooth needed, chipping seen for 5 prostheses (25%)	75%
Sorensen (7)	Prospective	36 months follow up time	19 (19 patients) FPP (3-piece)	Chipping seen in single prosthesis (10.52%)	90%

Table 1 cont.: Success rate of prostheses calculated.

Edelhoff (8)	Prospective	39 months follow up time	22 (18 patients) FPP (3- and 6-piece)	1 adhesive fracture of veneer ceramic, chipping seen in single prosthesis (9.09%), endodontic treatment of single tooth needed	90.5%
Molin (9)	Prospective	60 months follow up time	19 (18 patients) FPP (3-piece)	1 adhesive fracture 0 x chipping (0%)	98%
Crisp (10)	Prospective	12 months follow up time	38 FPP (3- and 4-piece)	Chipping seen in 2 prostheses (5.2%)	95.8%
Tinschert (11)	Prospective	37 months follow up time	65 (46 patients) FPP (3- and 10- piece)	Chipping seen in 4 prostheses (6.15%), endodontic treatment needed in 3 teeth, adhesive fracture seen in 2 prostheses	94%
Sailer (12)	Prospective	40 months follow up time	36 FPP (3-5-piece)	Endodontic treatment needed for single tooth, chipping seen in 9 prostheses (25%)	75%
Schmitt (13)	Prospective	34 months follow up time	30 (30 patients) FPP (3-4-piece)	Endodontic treatment needed for single tooth, chipping seen in 3 prostheses (10%)	90%
Schmitter (14)	Prospective	25 months follow up time	30 (27 patients) FPP (4-7-piece)	FPP fracture of single tooth due to mechanical failure of connector (3,33%) 2 adhesive fractures Chipping of single prosthesis (3.33%) endodontic treatment needed for single tooth	96%
Wolfart (15)	Prospective	48 months follow up time	24 (21 patients) FPP (3-piece)	Secondary caries leading to single tooth loss, endodontic treatment needed for 2 teeth, 2 adhesive fractures chipping of 3 prostheses (12.5%)	96%
Eschbach (16)	Prospective	54 months follow up time	65 (58 patients) FPP (3-piece)	1 complete fracture of FPP (1.53%) 1 tooth lost due to caries 2 adhesive fractures 4 x chipping (6.15%)	94%
Beuer (17)	Prospective	35 months follow up time	18 FPP and 50 one-piece crowns (38 patients)	Fractures found only in FFPs: single tooth needed endodontic treatment and removal of FPP indicated), chipping seen in 5 prostheses (27.77%) endodontic treatment was needed for 2 teeth plus 2 cases of secondary caries	88%
Roediger (18)	Prospective	50 months follow up time	99 prostheses that is 75 patients, FPP (3-4-piece)	Endodontic treatment needed for 1 tooth, secondary caries showed 3 cases, adhesive fractures 6 in number, chipping seen in 13 prostheses (13.13%) periodontal lesion lead to loss of single tooth	94%

Table 1 cont.-1: Success rate of prostheses calculated.

Schmitt (19)	Prospective	62 months follow up time	25 (25 patients) FPP (3- and 4-piece)	2 teeth needed endodontic treatment, chipping seen in 7 prostheses (28%), complete fracture of FPP, loss of 5 posts due to biological failure, single adhesive fracture	92%
Kern (20)	Prospective	74 months follow up time	20 number of FPP: 17 number of 3-piece and 3 number of 4-piece including 15 patients	Chipping seen in 3 prostheses (15%) and 1 tooth underwent endodontic treatment	85%
Peláez (21)	Prospective	36 months follow up time	20(17 patients) FPP (3-piece)	Chipping seen in 2 prostheses (10%)	90%
Rinke (22)	Prospective	84 months follow up time	99 FPPs including 81 number of 3-piece and 18 number of 4-piece With a total of 75 patients	12 fractures in FPPs; prosthesis that needed replacement. (12.12%) 19 x chipping (19.19%) 1 endodontically treated tooth fracture, periodontal disease causing loss of 2 teeth ,secondary caries leading to loss of 3 teeth, 4 secondary caries cases without tooth loss (vitality loss), adhesive fractures- 7 in quantity	83.5%
M. Baris, Güncü <i>et al.</i> (23)	Retrospective study	5 years follow up time	148 patients 618 single- or multiple-unit zirconia-based crowns	smooth veneer fracture (4, 0.6%), retention loss (7, 1%), smoke stains (24, 4%), recession of gingiva (48, 8%)	98%
Shoko Miura <i>et al.</i> (24)	Retrospective cohort study	12 years follow up time	56 subjects (137 crowns)	Out of the 21 crowns 16 crowns showed the utmost complication of ceramic veneer fracture	67.2%
Behnaz Ebadian <i>et al.</i> (25)			40 zirconia bars measuring 31 mm × 6.5 mm × 1.35 mm ± 0.1 mm	Thin porcelain layer next to the zirconia–porcelain interface failure seen. Segments of porcelain remained unbroken apart from 3 where slight chipping was seen marginally.	0%
F. O. Abu-Izze <i>et al.</i> (26)		No follow up	Sixty standard tabletop preparations	Zirconium-reinforced lithium silicate restorations offered random defects that ended in fracture, but hybrid ceramic restorations offered defects that amplified with mechanical fatigue next to little cycling time	36.8%
Rinke <i>et al.</i> (27)	Prospective study	10 years follow up time	75 patients with 99 posterior Fixed dental prosthesis	24 were mislaid to follow-up, 51 persisted functional, 13 were absolute failures caused by technical events	75%
Shoko Miura <i>et al.</i> (28)	prospective cohort study	3.5-year follow up time	40 monolithic zirconia crowns	Fracture of 2 crowns, abrasion of 1 crown, fracture of 1 antagonist crown	92.8%

Discussion

The studies were divided into groups - *In vivo* and *In vitro* studies.

-Fixed prostheses with zirconia substructure – *In vivo* performance in studies

The authors Pospiech (follow-up of 24 months) (2), Beuer (follow up of 40 months) (17), Bornemann (18 months) (3), Crisp (follow up of 12 months) (10), Tinschert (follow up of 37 months) (11), Schmitter (25 months follow up) (14), and Eschbach (follow up of 54 months) (16) evaluated chipping as the main cause of failure of the fixed prosthesis in their respective studies.

Vult von Steyern in his study with 24 months of follow up period (5), Peláez with follow up period of 36 months (21), Edelhoff (39 months of follow up)(8), Schmitt (follow up period of 34 months) (13), Wolfart (48±7 months of follow up time) (15), Roediger (50 months follow up)(18), Kern (follow up period of 74 months) (20), and Sorensen (follow up period of 36 months) (7) inferred an occurrence of chipping that ranges between 9-15% with the success rate of 91% to 85% in posterior fixed partial prostheses.

Finally, diversity in the studies carried out by Raigrodski (with 31months follow-up) (6), Sailer (40.3±2.8 months of follow up period) (12), Beuer (with 35±14 months follow up time) (17), Schmitt (62 months follow up) (19) and Rinke (follow up period of 84 months) (27) say that frequency of chipping of veneer material on posterior fixed partial prostheses is in the range of 19-28% with rate of success ranging from 72-81%. Few authors – Molin (with 60-month follow-up)(9) and Suárez (follow up period of 18 months)(4) didn't spot any mechanical problems amongst the restorations considered (Table 1-1 cont.-1)

-Fixed prostheses with zirconia substructure – *In vitro* performance studies

Concerning the mechanical performance of fixed prosthetic restorations, resisting the force of chewing deprived of getting fractured is the vital need. The first molar is exposed to a 300-800N force, although the anterior region is exposed to 60-200N of mastication force. Forces can exceed upto 1000N in few parafunctional cases (1). Oblique fractures were seen in maximum of the studies where the direction of force is towards occlusion from gingiva, from the center of the connector to the pontic's center (1).

Due to this reason a pontic fabrication area of 6-9mm² is recommended by most of the authors.

Classification given by Konstantinos along with Agustin for the fracture types (29) :

Cohesive (chipping): Fracture without disturbing the interface of ceramic core.

Adhesive: Fracture occurring at the ceramic to core bond. It is seen in various *in vitro* studies that when there is fracture in the samples, a cohesive fracture pattern is su-

ffered in the occlusal zone which is adjacent to antagonist's contact point.

Tsalouchou evaluated to static resistance loading of zirconia crowns which were 50 in quantity, analysing of the transversal plane by SEM analysis is done and also display that the most recurring type of fracture resulted as cohesive fracture(30). Similarly , Saito made a study of fracture resistance of porcelain-veneered of 72 samples with zirconia cores, concluding that the most recurring fracture type was cohesive fracture which comprises of 88.8% (31).

-Summary

The rate of success was significantly predisposed by site, with crowns seated in the molar area displaying further biological and technical difficulties than anterior crowns. Fractures of ceramic material were also knowingly influenced by site, with molar crowns showing knowingly more risk for these fractures than anterior crowns.

In vitro full-coverage restorations studies have seen a greater occurrence of cohesive type of fracture for zirconia restorations. The higher incidence of chipping is explained in a study by Martin Rosentritt (2009) that assayed zirconia restoration fracture resistance, finding that all samples suffered cohesive fractures due to inadequate performance of the veneer material (32).

Conclusions

The relationship between chipping phenomenon and risk factors occurring clinically, chiefly occlusal aspects, ought to be taken into consideration in upcoming prospective studies. Specific attention should be given by dental practitioners to clinical constraints when performing zirconia based restorations till an answer is found to enhance the mechanical resistance of the materials.

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Conflicts of interest

There are no conflicts of interest.