ZIRCONIA: CEMENTATION OF PROSTHETIC RESTORATIONS. LITERATURE REVIEW

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SUMMARY

Zirconia: cementation of prosthetic restorations. Literature review.

Aim of the work. Aim of the work was to execute a review of the international literature about the cementation of zirconia restorations, analyzing the properties of the cements most commonly used in clinical activities.
Materials and methods. It was performed, through PubMed, a bibliographic search on the international literature of the last 10 years using the following limits: studies in English, in vitro studies, randomized clinical trial, reviews, meta-analysis, guide-lines. Were excluded from the search: descriptive studies, case reports, discussion articles, opinion's leader.
Results. From studies results that common surface treatments (silanization, acid etching) are ineffective on zirconia because it has an inert surface without glassy component (on which this surface treatments act primarily), instead the sandblasting at 1atm with aluminium oxide (Al_2O_3) results significantly effective for the resulting roughening that increase the surface energy and the wettability of the material. Furthermore it has been shown that zinc phosphate-based cements, Bis-GMA-based and glass-ionomer cements can't guarantee a stable long-term adhesion, instead resin cements containing phosphate monomer 10-methacryloyloxyidecyl-dihyidrogenphosphate (MDP) have shown higher adhesion and stability values than the other cements. In particular, it has seen that bond strength of zirconia copings on dentin, using MDP-based cement, is about 6,9MPa; this value is comparable to that obtained with gold copings cementation.
Conclusions. Analyzed studies have led to the following conclusions: sandblasting with aluminium oxide (Al_2O_3) is the best surface treatment to improve adhesion between resin cements and zirconia; resin cements containing phosphate ester monomers 10-methacryloyloxyidecyl-dihyidrogenphosphate (MDP) have shown in the studies an higher bond strength and stability after ageing treatment; the best procedure for cementing zirconia restorations results the combination of sandblasting with aluminium oxide (Al_2O_3) at 50µm and MDP-based cements.

Key words: bonding, luting, zirconia ceramic, zirconium oxide ceramic, bond strength, surface treatments.

RIASSUNTO

Zirconia: cementazione dei restauri protesici. Revisione della letteratura.

Scopo del lavoro. Scopo del lavoro è stato eseguire una revisione della letteratura internazionale sulla cementazione dei restauri in zirconia, analizzando le capacità dei cementi più comunemente utilizzati nell'attività clinica.
Materiali e metodi. È stata eseguita, attraverso PubMed, una ricerca bibliografica della letteratura internazionale degli ultimi 10 anni inserendo i seguenti limiti: studi in lingua inglese, studi *in vitro, trial* clinici randomizzati, revisioni, meta-analisi, linee guida. Sono stati esclusi dalla ricerca: studi descrittivi, *case reports,* articoli di discussione e dibattiti (opinion's leader).
Risultati. Dagli studi risulta che i comuni trattamenti di superficie (silanizzazione, mordenzatura acida) si rivelano inefficaci sulla zirconia in quanto costituita da una superficie inerte e priva di componente vetrosa (su cui tali trattamenti agiscono principalmente), mentre risulta significativamente efficace il trattamento con sabbiatura mediante getto ad 1 atm di ossido di alluminio (Al_2O_3) che, con l'irruvidimento che ne deriva, si ha aumento dell'energia di superficie e della bagnabilità del materiale. Si è inoltre evidenziato che i cementi a base di fosfato di zinco, a base di Bis-GMA e vetro-ionomeri non garantiscono un'adesione stabile nel lungo periodo, mentre i cementi resinosi contenenti monomero fosfato 10-metacriloilossidecil diidrogeno fosfato (MDP) hanno mostrato valori di adesione e stabilità nel tempo superiore a tutti gli altri cementi. In particolare si è visto che la forza di adesione delle cappette in zirconia su dentina, con cemento contenente MDP, è circa 6,9MPa; tale valore è paragonabile a quello ottenuto con la cementazione delle cappette in oro.
Conclusioni. Basandosi sugli studi analizzati si è giunti alle seguenti conclusioni: la sabbiatura con ossido di alluminio (Al_2O_3) è il trattamento di superficie migliore per aumentare l'adesione tra cementi resinosi e zirconia; i cementi resinosi contenenti monomero esterico organofosfato 10-metacriloilossidecil diidrogeno fosfato (MDP) hanno dimostrato nei vari studi di una più alta capacità di adesione e stabilità dopo processo di invecchiamento; la migliore procedura per la cementazione dei restauri in zirconia risulta essere la combinazione di sabbiatura con ossido di alluminio (Al_2O_3) a 50µm e cementi contenenti MDP.

Parole chiave: adesione, cementazione, zirconia-ceramica, ossido di zirconio-ceramica , forza di adesione, trattamenti di superficie.

Introduction

Introduction of zirconia in dentistry has expanded the possible applications of metal-free ceramic restorations with greater success and reliability. This is due to the excellent optical and mechanical properties of this material. With introduction of CAD/CAM system production of zirconia restorations became a totally digitized process, and than faster and more accessible.
Thanks to its excellent biocompatibility, zirconia is also used as prosthetic implant for medical and dental purposes. Chemical and dimensional stability makes it a good material for prosthetic rehabilitation. Furthermore, zirconia has a dense and hard surface which gives an higher resistance to wear.
On the other hand its great surface stability creates several problems especially as regards the efficiency and duration of the chemical or mechanical bond with the different cementing systems. Use of common etching with hydrofluoric acid in combination with silanization, previously used for the other ceramic systems, has not proven useful against the high acid resistance of zirconia due to the absence of glassy matrix on which these substances act (1).
Different cementing agents has been analyzed and only those containing an organophosphate ester monomer have shown a significant efficacy. In agreement with recent studies it has seen that the combination of sandblasting and phosphate monomer 10-methacryloyloxyidecyl-dihyidrogenphosphate (MDP) is the best for cementation with resin composite (2).
Unfortunately there aren't enough studies on the mechanism of MPD adhesion and it is not clear whether there is a true chemical bond with zirconia or there is a micro-retentive bond promoted by sandblasting. Furthermore, there are insufficient data regarding long-term *in vivo* performances of resin composite containing MDP and the effect of hydrolysis on bond strength (3, 4).
Silaning agents are known and widely used for creating covalent bonds between matrices of different nature, such as glassy oxides of classic ceramics and organic monomer. In particular, silane, that binds the methacrylate monomer (3-methacryloyloxypropyl-trimethoxylane) is widely used in dentistry (5). Nevertheless silaning agents can't react with the surface of zirconia as inert (2, 6).
Aim of this study is to analyze, through the international scientific literature, the different cementation systems currently available for zirconia prosthetic restorations.
In particular, have been analyzed: adhesion strength of different cements, the influence of surface treatments on bond strength, effects of aging process on cement-zirconia interface, the best combination of surface pre-treatment and cementation currently available for zirconia's prosthesis.

Material and methods

It was performed, through PubMed, a bibliographic search on the international literature. Have been searched studies from January 2000 to January 2010. Following words were searched: cementation of dental zirconia, studies in English language, *in vitro* studies, randomized clinical trial, review, meta-analysis, guideline.
Following words were excluded: cementation of endodontic post, descriptive studies, case reports, discussion articles, opinion's leader.
MeSH terms (Medical Subject Headings) used were: bonding, luting, zirconia ceramic, zirconium oxide ceramic, bond strength, surface treatments. From 63 articles have been extrapolated 8.

Discussion

Nowadays we haven't an ideal system for cementing zirconia restorations on dental tissues (7).
There is a widely choice of materials for cementing metal-free restorations. These include: zinc phosphate, conventional and modified glass-ionomer cements, resin cements and self-adhesive cements (8). Anyway, resin cements have several advantages over other cements, such as a lower solubility and higher optical properties (8, 9).
Shear bond strength of 11 cements on zirconia was evaluated by Piwowarczyk et al. (8). Results indicated that zinc phosphate and both conventional and mo-

dified glass-ionomer cements aren't able to form a lasting bond with zirconia; only Rely X Unicem (resin cement) and Panavia F2.0 (resin cement containing MDP monomer) show good results even after aging. From study of Luthy et al. (9) was seen that bond strength of glass-ionomer cements and conventional Bis-GMA-based composites is significantly lower, especially after aging by thermocycling. Only Rely X Unicem and Panavia F2.1 withstands such procedure, with the latter achieves high bond strength.
Clinical reality seems to be different because, from the study of Palacios et al. (10), where was evaluated the force required to remove coping cemented on extracted teeth along the path of insertion. From this study was seen that Panavia F2.0 (resin cement containing MDP monomer), Rely X Luting (modified glass-ionomer cement) and Rely X Unicem (resin cement) are able to give sufficient adhesion to the zirconia's copings, respectively 6,9MPa, 8,5MPa, 6,7MPa, without requiring other surface treatment except sandblasting. Such values are comparable to those obtained with cementation of gold casting (11). Such results are in according with study of Ernst et al. (12), realized in the same way with 8 cements, where are found high values of adhesion for the cements mentioned in the previous study, and also for Superbond C&B (resin cement). In such studies must also be considered the design of preparation as a retentive factor, so it can't obtain an accurate assessment of adhesive properties of various cements.
Wegner et al. (3) have evaluated the shear bond strength of 5 cements, before and after long term stocking (2 years) and thermocycling at 37500 cycles. It was evaluated also the efficiency of different surface treatment as sandblasting with aluminium oxide (Al_2O_3) at 50µm and silanization. It is resulted that Bis-GMA-based cements have not long term stability, surface treatments improve the initial bond strength but their effect decrease with time. Only resin cements with phosphatic monomer (Panavia F2.1) have shown high adhesion values and reliability after thermocycling in association with sandblasting.
The study of Derand et al. (13) has evaluated different surface treatments with composite cements (Superbond C&B, Twinlook, Panavia F2.0) and resulted that etching with hydrofluoric acid at 10% and sandblasting have just a minimal effect to improve adhesion. It has also been seen that composite cement Superbond C&B shows higher adhesion values.
In the study of Wolfart et al. (14) it was evaluated the adhesion of 2 resin cements (Variolink, Panavia F2.0) at 3 and 150 days (the latter sample was thermocycled at 37500 cycles). Half of the samples was sandblasted. It resulted that only cement containing phosphate monomer, in association with sandblasting, can obtain higher and durable adhesion values.
The study of Re et al. (15) analyzes, in particular, the efficacy of the several pre-treatment of zirconia surface in improving adhesion of Rely X Unicem and Panavia F2.0. It showed that sandblasting gives best results due the roughening resulting that allows for better micro-retention of the cement.
From all those studies it has been seen that resin cements containing phosphate monomer 10-methacryloyloxyidecyl-dihyidrogenphosphate (MDP) allows to better and lasting results than the other cements. MDP monomer could make a chemical bond with metal oxides, such as zirconium oxide (9, 14). In fact almost 100% of cementation failure modes observed in several studies (9, 10, 14) were cohesive type.
Among surface treatments only sandblasting showed a significant adhesion improvement, in association with resin cements containing MDP (10, 13, 14). Although there are studies indicating sandblasting as factor adversely affecting for the surface of zirconia, which would lead to a reduction of flexural strength (16), there are other Authors that contrast this view and indeed see this process as a factor strengthening the surface, promoting transformation toughening (17). A detrimental effect on material performance, due to microfractures caused by sandblasting, is now questionable. Surface roughening is necessary to increase the surface energy and the wettability of the material (18). Acid etching has not proved effective because it act on the glass matrix (present in silica-based ceramics) dissolving it and creating a rough surface. Zirconia does not contain glass matrix, so it can't be altered by acid attack (13).
Silanization is used to create chemical bonds between glass matrix of classic ceramics and resin cements (5). For the same reasons previously indicated this process may not be on the surface of zirconia (18). The studies examined were summarized in the Table 1.

Table 1 - Zirconia bridges strength.

Articles	Cases treated	Parameters evaluated	Surface treatments	Conclusions
Derand et al. 2000	3 cements on composite cylinders (n=10)	Shear bond strength after water storage for 5h, 1d, 7dd, 2mm	Sandblasting with Al_2O_3 at 250µm, sandblasting with Al_2O_3 at 50µm, etching with hydrofluoric acid at 37%, roughening with diamond burr	Resin cements show higher bond values. Surface treatments don't provide significant benefits.
Wegner et al. 2000	5 cements on plexiglass (n=16)	Shear bond strength after water storage 3dd, 2yy + thermocycling at 5-55°C x 37500 cycles	Sandblasting with Al_2O_3 at 50µm, silanization	Bis-GMA-based cements are not stable. Cements containing MDP in association with sandblasting give better results
Ernst et al. 2005	8 cements on dentin (n=10)	Axial displacement after thermocygling at 5-55°C x 5000 cycles	Silanization	There aren't significant differences in bond strength of different cements. Silane doesn't improve the adhesion
Piwowarczyk et al. 2005	11 cements on epoxy resin (n=20)	Shear bond strength after 30' from cementation and after water storage for 14dd + thermocycling at 5-55°C x1000 cycles	Sandblasting with Al_2O_3 at 100µm, silanization	Zinc phosphate and glass-ionomer cements don't give stable adhesion. Cements containing MDP show higher and more stable adhesion
Palacios et al. 2006	3 cements on dentin (n=12)	Axial displacement after thermocycling at 5-55°C x 5000 cycles	Sandblasting with Al_2O_3 at 50µm	All 3 cements are able to provide a sufficient retention at the coping, without requiring surface treatments beyond sandblasting
Luthy et al. 2006	5 cements on stainless steel (n=30)	Shear bond strength after water storage 2dd or thermocycling at 5-55°C x 10000 cycles	Sandblasting with Al_2O_3 at 110µm	All cements lose resistance after thermocycling except those containing MDP
Wolfart et al. 2007	2 cements on plexiglass (n=20)	Shear bond strength after water storage for 3dd or 150dd + thermocycling at 5-55°C x 37500 cycles	Sandblasting with Al_2O_3 at 50µm	Cements containing MDP + sandblasting provide greater and lasting adhesion
Re et al. 2008	2 cements on stainless steel (n=40)	Shear bond strength after water storage for 7dd	Sandblasting with Al_2O_3 at 110µm, sandblasting with Al_2O_3 at 50µm, silanization	Cements containing MDP provide greater adhesion and are less influenced by the surface treatments. Sandblasting improves significantly adhesion

Conclusions

Basing on analyzed studies in this literature review we reached at the following conclusions:
Sandblasting with aluminium oxide (Al_2O_3) is the best surface treatment for improving adhesion between resin cements and zirconia. Although some studies have indicated this treatment as potentially damaging for mechanical properties of the material there aren't evidences showing this hypothesis.
Silanization and acid etching are not effective on zirconia because it is inert and without glassy matrix on which those substances act.
Zinc phosphate cements, glass-ionomer cements and conventional Bis-GMA-based cements have shown a low adhesion.
Resin cements containing esteric organophosphate monomer (MDP) have shown in different studies a higher capacity of adhesion and stability after aging process; this is attributed to the capacity to bind metal oxides such as zirconium oxide (ZrO_2).
The best procedure for cementing zirconia restorations is the combination of sandblasting with aluminium oxide (Al_2O_3) at 50µm and Panavia F2.0 containing MDP.
Long-term clinical studies are necessary to evaluate the binding capacity and stability of materials for cementing the zirconia surface.

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