Does the surface conditioning of glass and hybrid ceramics with self-etching silane present a bond strength similar to that of conventional bonding? Systematic review and meta-analysis of in vitro studies.

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Compiled by Dr Francis Chan.

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Introduction

Ceramic materials are widely used in oral rehabilitation due to their favourable mechanical, optical, and physical properties that closely resemble natural tooth structure. With the increasing use of computer-aided designs and computer aided-manufacturing technology in dentistry, a variety of ceramic materials has emerged. These can be classified as glass, polycrystalline, or hybrid ceramics. Glass ceramics are non-metallic inorganic materials that have a glassy phase in their composition, including feldspathic ceramics. Hybrid ceramics are those with a resinous matrix, also known as polymer-infiltrated ceramics.

Achieving durable adhesion between ceramic restorations and resin cement is critical for long-term clinical success, and this is heavily influenced by the surface conditioning method, adhesion system, and cementing agent. Conventional surface treatment typically involves 4-5% or 9-10% hydrofluoric acid (HF) etching followed by silane application. HF selectively dissolves the glass phase, creating a rough and porous surface that enhances micromechanical retention, increasing surface energy and facilitating silane wettability. Silane facilitates chemical bonding between the ceramic silicon oxides and the resin cement's organic matrix. This protocol is technique-sensitive, involves multiple steps, and may induce adverse effects such as toxicity, microcracks, and fissures on the ceramic surface.

Self-etching ceramic primers have been introduced to simplify the procedure, combining acidic monomers and silane into a single-step system. Studies have shown that self-etching primers promote a less aggressive corrosion pattern than HF, however it is unclear whether they provide bond strength comparable to conventional HF etching with silane. This systematic review and meta-analysis aimed to evaluate the bond strength of glass and hybrid ceramics treated with self-etching primers compared with conventional HF-based protocols through in vitro studies, considering the application of different concentration of HF and silane with or without ageing. The null hypothesis was that self-etching primers would exhibit a similar bond strength to HF etching.

Materials and Methods

This study was conducted as a systematic review and meta-analysis using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement guidelines. A population, intervention, control, and outcome (PICO) question was formulated: "Does the surface conditioning of glass and hybrid ceramics with self-etching silane present a bond strength similar to that of conventional bonding?". The population (P) was composed of samples of glass and hybrid ceramics. The intervention (I) was the use of self-conditioning techniques. The comparison (C) consisted of surface treatment with

hydrofluoric acid. The outcome (O) was the analysis of bond strength. Eligibility criteria were: (1) in vitro studies; and (2) studies analysing the bond strength of glass and hybrid ceramics subjected to self-etching surface treatment. Exclusion criteria were: (1) polycrystalline ceramics; (2) analyses of bond strength between infrastructure and covering ceramics; (3) studies without comparison to conventional treatment.

A bibliograph search was performed across PubMed, Embase, Web of Science, and Cochrane Library databases up to September 2023. Manual searches were performed in non-peer-reviewed literature using the ProQuest database. Two independent reviewers conducted study selection based on titles and abstracts, and applied eligibility assessment with disagreements resolved by consensus with a third reviewer.

The quality of the included articles was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist. Studies which scored five or more out of the eight criteria were considered of good quality. Meta-analysis was performed using the inverse variance method, with mean differences and 95% confidence intervals calculated, and statistical significance set at $p < 0.05$. Inter-examiner agreement during study selection was assessed using kappa statistics and demonstrated high reliability across databases.

Results

The search yielded 292 studies, of which 29 studies (representing a total of 1889 ceramic samples) met the inclusion criteria. Most studies investigated glass ceramics, while a smaller proportion included hybrid ceramics. The JBI Critical Evaluation Checklist indicated a low risk of bias, and all studies met more than 60% of criteria which indicated high quality.

Fifteen studies reported higher bond strengths with self-etching primers, whereas thirteen studies reported superior results with conventional HF etching and silane. In the last remaining study, self-etching primers increased bond strengths for glass ceramics but reduced bond strengths for hybrid ceramics.

The meta-analysis excluded a further three studies due to not reporting mean results and/or standard deviations, and one study for not reporting the concentration of HF used. Therefore 25 studies were considered for meta-analysis. When compared with lower HF concentrations (4-5%) combined with silane, self-etching primers resulted in significantly higher bond strength values. However, no significant difference was noted after ageing. When compared with higher HF concentrations (9-10%) combined with silane, no statistically significant difference in bond strength was observed. There was low heterogeneity of the included studies.

Discussion

The null hypothesis that self-etching primers would exhibit a similar bond strength to HF etching could not be rejected. This result was interpreted as a favourable indication of the use of self-etching primers as it overcomes the limitations and disadvantages of conventional etching.

HF removes part of the glass matrix in ceramics which creates irregularities and improves the bond between the ceramic and resin cement. Self-conditioning primers (e.g., Monobond Etch & Prime) contains ammonium polyfluoride as the etching component and a silane coupling agent based on trimethoxysilylpropyl methacrylate.

Ceramics treated with self-etching primer exhibited higher bond strengths than those treated with low concentrations of HF (4-5%). This may be related to the conditioning time. Low concentrations of HF produced a shallower dissolution of the vitreous matrix, resulting in lower bond strengths. The reduced strength was especially evident for leucite ceramics which have a higher glass phase content. A longer-etching time with HF may be necessary with these materials, however this has been linked to weakening of the ceramic due to increased removal of the glass phase. Hybrid ceramics also tend to suffer greater degradation in material properties when subjected to acids due to weakening of the resin matrix and breakdown of the inorganic fillers. However, the meta-analysis in this study did not find differences in bond strength between self-etching primers and HF (4-10%) in the context of hybrid ceramics.

The meta-analysis showed that the bond strength after ageing of ceramic surfaces subjected to the self-etching technique resulted in a less rough surface compared with the conventional technique, but allowed for compatible micromechanical interlocking, maintaining an adhesive behaviour similar to the use of HF at any concentration after ageing. Shear stress testing (parallel forces applied in the opposite directions) showed similar performance between ceramic surfaces treated with self-etching silane, and those treated with the conventional technique.

The authors suggested self-etching primers were a better clinical option compared with the conventional technique of using HF followed by silane because it reduces the number of clinical steps and presented with satisfactory long-term bond strength. The authors recommended further investigations, particularly clinical trials with follow-up.

Conclusion

Within the limitations of in vitro studies, self-etching ceramic primers demonstrate bond strength that is either superior to or comparable with conventional HF etching and silane treatment for glass and hybrid ceramics.

Questions

1. What was the null hypothesis of this systematic review?
   A. Self-etching primers are superior to HF etching.
   B. Self-etching primers have similar bond strength to HF etching.
   C. HF etching is inferior to silane alone.
   D. Hybrid ceramics bond better than glass ceramics.

2. What is the primary mechanism of HF etching on glass ceramics?
   A. Silanisation.
   B. Dissolution of the glass phase.
   C. Dissolution of the resin matrix.
   D. Dissolution of the inorganic fillers.

3. What is a major disadvantage of conventional HF etching?
   A. Low bond strength
   B. Incompatibility with resin
   C. Technique sensitivity and toxicity
   D. High cost

4. What is the key function of silane in ceramic bonding?
   A. Increase surface roughness
   B. Provide chemical coupling between the ceramic silicon oxides and organic matrix of the resin cement
   C. Reduce ceramic microcracks
   D. Improve wettability of the ceramic surface

5. Self-etching primers combine which components?
   A. Adhesive and resin
   B. Acid, monomers, and silane
   C. Silane and cement
   D. HF and resin

6. How many studies were included in the meta-analysis?
   A. 4
   B. 25
   C. 29
   D. 44

7. A longer HF etch time may be indicated for which class of materials?
   A. Leucite ceramics
   B. Hybrid ceramics
   C. Polycrystalline ceramics
   D. Resin cements

8. A limitation of the present study was:
   A. Only in vitro studies were included
   B. Ageing of the specimens was not assessed
   C. Small sample size
   D. High heterogeneity of the included studies

9. Self-etching primers produced significantly higher bond strengths when compared with:

A. 9-10% HF with silane when there was no ageing of the samples.
B. 9-10% HF with silane when there was ageing of the samples.
C. 4-5% HF with silane when there was no ageing of the samples.
D. 4-5% HF with silane when there was ageing of the samples.

10. Is this statement true or false- “Based on the meta-analysis, self-etching primers used produced lower bond strengths for hybrid ceramics when compared with HF and silane.”
A. True
B. False