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Is mechanical retention for adhesive core build-up needed to restore a vital tooth with a monolithic zirconium crown? – An in vitro study

KATARZYNA WALCZAK[1]*, STEFAN RUES[2], MIESZKO WIECKIEWICZ[3], URSULA RANGE[4], MARC SCHMITTER[2]

[1] Department of Prosthetic Dentistry, Faculty of Medicine Carl Gustav Carus, Technische Universität Dresden, Dresden, Germany.
[2] Department of Prosthodontics, University Hospital Heidelberg, Heidelberg, Germany.
[3] Division of Dental Materials, Faculty of Dentistry, Wrocław Medical University, Wrocław, Poland.
[4] Institute for Medical Informatics and Biometry (IMB), Faculty of Medicine Carl Gustav Carus, Technische Universität Dresden, Dresden, Germany.

Purpose: To show the influence of retentive cavity, cavity wall preparation and different luting techniques on the fracture resistance of severely damaged teeth restored with adhesive core build-ups and monolithic zirconium crowns. *Methods:* Extracted molars were prepared with 2 mm ferrule height and divided into eleven groups (n = 8/group). In nine groups a retentive occlusal cavity with a width and depth of 1 or 2 mm was prepared. Two control groups without a retentive cavity were made. Zirconium crowns were manufactured. 48 copings were cemented with glass-ionomer cement (Ketac Cem), the others (n = 40) with adhesive resin cement (Panavia F 2.0). Artificial ageing was carried out in the following way: n = 88, thermocycling (10,000 cycles, 6° C/60° C), n = 80 chewing simulation (1,200,000 cycles, 64 N). The samples were tested for load at first damage and fracture load with non-axial force. For statistical analysis ANCOVA with post hoc, Bonferroni-adjusted t-test were used ($p \leq 0.05$). *Results:* No differences between the tested cements were detected. Influence of the cavity wall thickness was significant (p = 0.001). Mostly, the samples with wall thickness of 2 mm showed better results. Both control groups (no cavity) showed results comparable to study groups with cavity. *Conclusions:* Retentive cavity is most likely not mandatory. However, if prepared, the cavity wall thickness is of higher importance than cavity depth. Glass-ionomer and adhesive resin cement are comparable for use with zirconia crowns.

Key words: *core build-up, luting agent, MDP, retentive cavity, zirconia, fracture resistance*

1. Introduction

Amalgam, glass-ionomer and composite resin are described and used as core build-up materials [23]. Composite resins are most popular and recommended for teeth with extensive loss of hard tissue because of their good adhesive bond to tooth structure as well as their suitable compressive strength and aesthetics [23]. Glass-ionomer shows an inadequate bond strength, both amalgam and glass-ionomer need additional mechanical retention to establish sufficient retention on compromised teeth without retentive structures [23].

Only a few studies described core build-ups on teeth with severe coronal tissue destruction for cast crowns, ceramic copings and direct restorations [16], [21], [22], [24].

On the other hand, only one study [24] reported about the reconstruction of severely destroyed teeth without endodontic treatment using zirconia crowns. However, it might be useful to preserve the vitality of abutment teeth: Rinke et al. [17] showed that there is

* Corresponding author: Katarzyna Walczak, Department for Prosthetic Dentistry, Medical Faculty Carl Gustav Carus, Technische Universität Dresden, Fetscherstr. 74, 01307 Dresden, Germany. Tel: 00493514582706, e-mail: katarzyna.walczak@uniklinikum-dresden.de

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a higher risk of complications for zirconia crowns on endodontically treated teeth. In addition, endodontic treatment is connected with the following risks: perforation, fracture of instruments as well as reinfection. Teeth which underwent endodontic treatment have an estimated weighted pooled success rate of 68%–85% for at least 4 years (strict review criteria) [14]. Sometimes an extra post and core build-up is needed to improve the retention of crowns. Furthermore, post insertion is associated with risks such as root fracture [23]. In conclusion, it is very important to investigate the possibilities of restoring severely compromised but still vital teeth without the need of endodontic treatment.

The use of ceramic restorations has been increasing during the last 20 years. The development of the materials as well as the designing and manufacturing process open up more and more application possibilities in dentistry. Especially zirconia ceramics due to their excellent mechanical and biological properties find broad use in dentistry, i.e., as fixed dental prostheses (FDPs), posts, implants and abutments [1], [13]. Larsson and Wennerberg [11] showed a clinical success of 95.9% for tooth-supported zirconia based crowns. The main complications were loss of retention, endodontic treatment, fracture of veneering material and bleeding on probing [11]. Due to the complicated manufacturing process of veneered zirconia as well as their propensity to chip, monolithic zirconia crowns and bridges are suggested [13].

The aim of the present study was to investigate the influence of a retentive cavity in the center of the teeth, cavity wall preparation, luting techniques as well as the influence of tooth size (cross-section area) on fracture loads (load at first damage – F1 and maximal fracture load – Fmax) of teeth restored with zirconia copings.

The null-hypothesis was that the fracture resistance of teeth restored with zirconia crowns is independent of a retentive cavity, cavity wall preparation, cement or tooth cross-section area (tooth size).

2. Materials and methods

For the in vitro study a modified method from Schmitter et al. [21] was used (Fig. 1). Ethical approval S-034/2010 (University Hospital Heidelberg, Germany) for using human material was obtained. 88 human, extracted and not damaged, caries and filling-free third molars with completed root growth were used. Directly after extraction, the teeth were stored in

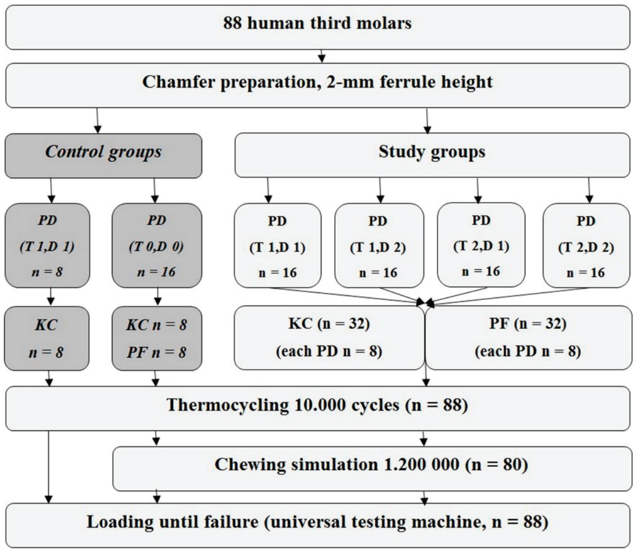

Fig. 1. Flow chart of the study. Preparation design (PD), Ketac Cem (KC), Panavia F 2.0 (PF)

0.1% thymol solution. The teeth were cleaned with a hand scaler and a dental air scaler (Sonicflex 2003 L, KaVo Dental GmbH, Biberach/Riß, Germany). The cusps of the teeth were completely removed horizontally using a rotating machine (DP-U2, Struers, Ballerup, Denmark) and emery paper with grain size of 220 µm (Struers, Ballerup, Denmark). Small cavities were milled into the palatinal root surfaces and the root apex was closed with Pattern Resin LS (GC Germany GmbH, Bad Homburg, Germany), to increase the tooth retention in the resin blocks. All teeth were embedded in Palapress blocks (Heraeus Kulzer GmbH, Hanau, Germany) along the tooth axis and 4 mm under the occlusal surface using a special silicon form and parallelometer (VG 3, Degussa, Frankfurt, Germany). Chamfer preparations with 2 mm ferrule height were established using tapered diamond burs (80 µm, no. 6254, 40 µm no. 6260, C. Hafner GmbH & Co., Pforzheim, Germany). The teeth were randomly distributed into eleven groups (n = 8). Different occlusal cavity designs were established: four combinations (n = 64) resulted in a cavity preparation with a 1 or 2 mm wall thickness and a depth of 1 or 2 mm (Fig. 2a). The two control groups did not contain a retentive cavity (n = 16). By the preparation of the occlusal cavity, in three cases the pulp chamber was opened accidentally. These samples were excluded and replaced. In addition, two different luting agents were used: glass-ionomer cement (Ketac Cem, 3M ESPE, Seefeld, Germany [KC], n = 40) and universal MDP (10-methacryloyloxydecyl dihydrogen phosphate) modified resin cement (Panavia F 2.0, Kuraray Dental, Okayama, Japan [PF], n = 40). In order to

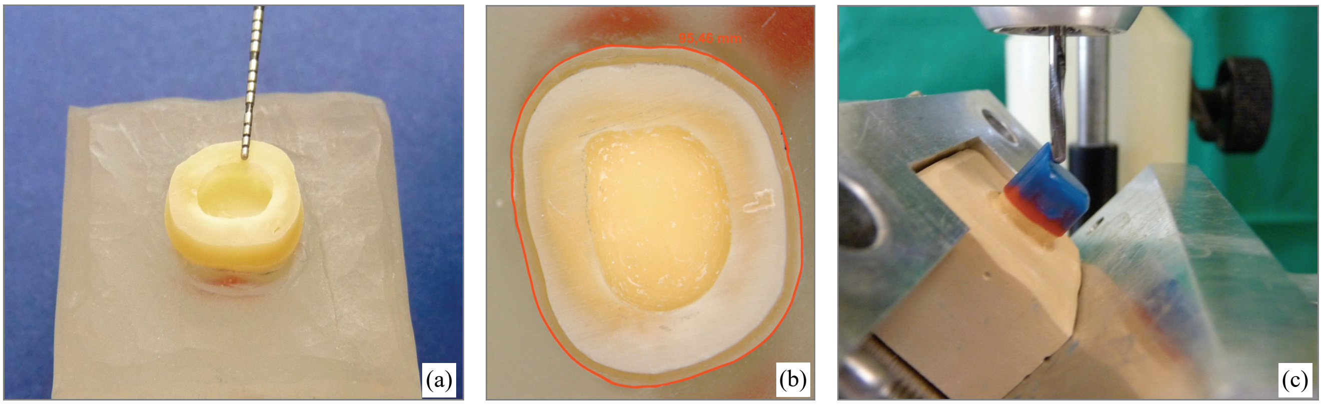

Fig. 2. Photographs showing the process of manufacturing samples:
(a) standardized preparation, (b) measurement of the tooth cross-section area, (c) milling of a wax crown

prove the effect of chewing simulation, a third control group with a box preparation design with a 1 mm cavity wall thickness and depth was prepared and cemented using Ketac Cem ($n = 8$). In this group, chewing simulation was omitted.

During the preparation, the reproducibility and parallelization of the tooth and bur axis were guaranteed by using an air turbine (TDS/STS 890, Bien-Air Dental SA, Bienne, Switzerland) with water cooling (50 ml/min) in a milling machine (type F1, Degussa, Frankfurt, Germany).

To calculate the cross-section area of the teeth, all prepared samples were photographed with the microscope camera (AxioCam MRC, Carl Zeiss, Göttingen, Germany). The tooth cross-section area on the chamfer preparation margin was measured using AxioVersion software (version 40 V 4.6.3., Carl Zeiss, Göttingen, Germany, Fig. 2b).

Before restoring using the composite based self-curing flowable adhesive core build-up material Rebilda SC (VOCO GmbH, Cuxhaven, Germany), the teeth were cleaned with water. The dentin was etched for 15 s with 35% Vococid etching gel (VOCO GmbH, Cuxhaven, Germany), rinsed with water and the residual humidity was removed with an oil-free airflow. A possible over-drying of the tooth structure was avoided. This was followed by the application of the primer for 30 s (Solobond Plus, VOCO GmbH, Cuxhaven, Germany), the drying with an oil-free airflow and the application of an adhesive (Solobond Plus, VOCO GmbH, Cuxhaven, Germany) as well as its distribution with an oil-free airflow. The adhesive was polymerized for 20 s (Bluephase C8, Ivoclar Vivadent GmbH, Ellwangen, Germany). According to the instructions of the manufacturer, the application and polymerization of a second layer of the adhesive was repeated. Rebilda SC core build-ups were made using a dental matrix band, which separate core build-up material from previously prepared tooth part with ferrule design. After the curing time of 7 minutes, the reconstructed teeth were circularly finished with previously used tapered diamond burs and air turbine which was clamped in the milling machine. Thereby, the chamfer of 0.5 mm was not modified. The convergence angle of the preparation was 4°. The core build-ups were flattened to a total height of 6 mm. Silicon impressions (Deguform, DeguDent GmbH, Hanau, Germany) and stone casts (GC Fujirock EP class IV, GC Europe, Leuven, Belgium) were made. Zirconia crowns were fabricated using the CAM technique. Specially designed wax copings (occlusal thickness 1 mm, circular thickness at least 0.6 mm and a buccal cusp with 2 mm height and width, as well as an inclination of 45°) were manufactured in a milling machine (S3-Master, Georg Schick Dental GmbH, Schemmerhofen, Germany, Fig. 2c).

The design of the buccal cusp allowed the loading of the crowns at a 45° angle to the tooth axis. The wax copings were scanned and the zirconia crowns were milled using a Cercon Brain milling machine (DeguDent GmbH, Hanau, Germany). The sintering process took six to seven hours at a temperature of 1350° C in a Cercon heat sintering oven (DeguDent GmbH, Hanau, Germany).

The zirconia crowns were adapted to their cast models as well as to the prepared teeth with special diamond burs (ZR 8379, 6379, 8881, 6881, Komet/Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany) and air turbine with water cooling (TDS/STS 890).

This was followed by cementing the zirconia crowns with a glass-ionomer cement (Ketac Cem) and a universal resin cement (Panavia F 2.0). Inner crown surfaces were blasted with 50 μm aluminium oxide at a distance of 1 cm (Vol. 5) using 1.5 bars for Ketac Cem and 2.5 bars for Panavia F 2.0 [9]. Afterwards, the residual aluminium oxide in the crowns was removed using 70% ethanol and an oil-free airflow. All prepared teeth were cleaned with a 3% hydrogen peroxide solution. Ketac Cem was prepared according to the instructions of the manufacturer. The crowns with cement inside were placed on the teeth and the excess cement was removed with foam pellets. The curing time was 7 minutes. When cementing with Panavia F 2.0, the Alloy Primer (Kuraray Dental, Okayama, Japan) was applied on the inner side of the crown after sandblasting and cleaning. The dentine was etched for 15 s with Vococid etch gel. The crowns were cemented using ED-primer (Kuraray Medical Inc., Okayama, Japan) and Panavia F 2.0 according to the instructions of the manufacturer. Cement residues were removed and Oxyguard II Gel (Kuraray Medical Inc., Okayama, Japan) was applied for 3 minutes. The curing process of all specimens (n = 88) occurred under finger pressure with medium force.

After cementing, the samples were stored in a 0.1% thymol solution for 24 h and after that in purified water at 37° C. The time until thermocycling was a maximum of 7 days. Purified water was also used as a medium for the artificial aging process (thermocycling and chewing simulation). The specimens were thermocycled with 10,000 cycles in a warm bath of 60° C and a cold bath of 6.5° C (Thermocycler THE 1100 SD Mechatronik GmbH, Feldkirchen-Westerham, Germany). The particular dwell time was 45 s and the drip 2 s. To simulate chewing movements, the samples were charged with 1,200,000 cycles in the chewing simulator (CS 3, SD Mechatronik GmbH, Feldkirchen-Westerham, Germany). During chewing simulation, all samples were tilted by 45° such that the buccal cusp was oriented horizontally and loaded vertically with a force magnitude of 64 N (mass m = 5 kg, descending speed v = 30 mm/s, spring k = 43 N/mm, damper d = 135 Ns/m; frequency f = 1.6 Hz). The third control group (KC, retentive box: 1 mm depth, 1 mm width) was only thermocycled.

After artificial ageing, the samples were loaded until fracture in a universal testing machine (Zwick Roell ProLine Tischprüfmaschine Z005, Ulm, Germany). The initial force was adjusted to 2 N, the cross-head speed was 0.5 mm/min. A cut-off threshold of 100 N was determined. Again, the specimens were loaded with a non-axial force tilted by 45° with respect to the tooth axis. The load application site was in the middle of the buccal cusp, 8 mm above the preparation margin. To avoid non-uniform loading along the buccal cups, the punch was coated with a 0.4 mm thick tin foil. Additionally, the test specimens were clamped into a specially made metal block, which ensured the correct load angle (Fig. 3a). The load at first damage (F1 in N), defined as the first drop of the force/displacement curve, as well as the fracture load (Fmax in N) were evaluated (Fig. 3b). The specimens were monitored during the tests. Damaging of the sample before the final fracture was noted in a protocol.

Statistical analysis was carried out using the SPSS Program (version 23, IBM Germany GmbH, 71137 Ehningen). The analysis of variance with a covariate (ANCOVA) with post hoc, t-test (Bonferroni adjusted) was calculated.

The specified p-values represent the descriptive values and differences were considered as statistically significant at values of $P \leq 0.05$. Specimens that failed during artificial ageing were included in the statistical analysis.

Loads of 0 N or 64 N were set for samples that failed in thermocycling or during chewing simulation, respectively. Thus, a comparative analysis of all samples was possible. For the initial fracture load one missing value was noted.

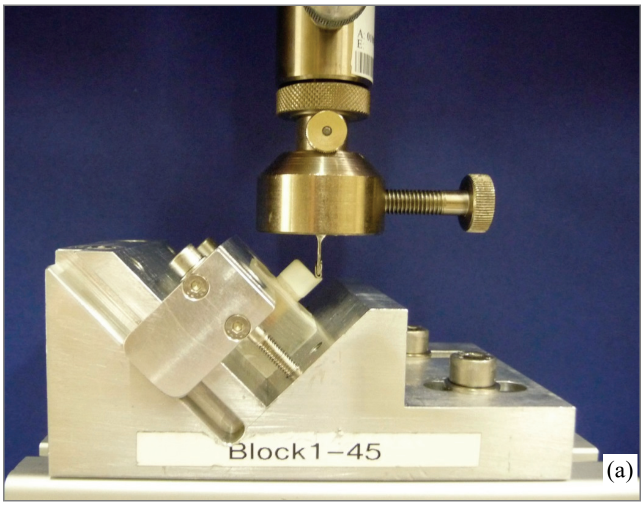

Fig. 3a. Loading of the samples at 45° to tooth axis in a universal testing machine

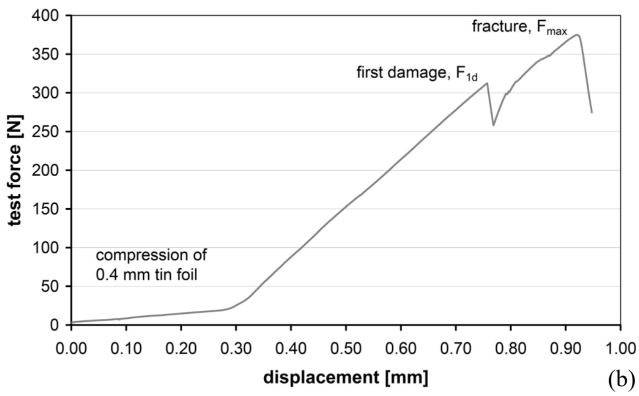

Fig. 3b. Exemplary force-displacement diagram

3. Results

Tooth cross-section area

The means of tooth cross-section area are described in Table 1. The ANCOVA analysis of all groups revealed a significant influence of tooth cross-section area (as a covariate) on the load at first damage (p = 0.05). Analyzing all groups with respect to fracture load, the tooth cross-section area, as a covariate, showed a tendency to influence the results (p = 0.1).

Failure modes

The samples were evaluated after fracture load test and classified on the basis of the failure pattern.

Due to the different failure patterns the division took place in four main groups: tooth fracture (n = 27, Fig. 4a), core build-up failure (n = 57), ceramic failure (n = 1) and decementation (n = 3, Fig. 4b). Core build-up failures were also divided into: core build-up failure without tooth fracture (debonding n = 16, debonding and build-up fracture n = 2), core build-up and tooth fracture (n = 17, Fig. 4c), core build-up and ceramic failure (n = 15) and core build-up combined with decementation (n = 7), (Table 1).

Failure during artificial aging

During thermocycling three crowns failed (3.4%, failure mode: decementation), two in the PF-group and one in the KC-group. Ten samples (12.5%) failed during chewing simulation (Table 1).

Table 1. Loads at first damage/final fracture loads and failure modes for study and control groups

Luting agent	T [mm]	D [mm]	Pretest failures	Failure mode A	B	C	CS [mm^2] mean ± SD	F1 [N] mean ± SD	Fmax [N] mean ± SD
Ketac Cem [n = 40]	1	1	3	2	6	0	88 ± 20	296 ± 212	304 ± 220^{a}
	1	2	3	3	5	0	75 ± 11	91 ± 89^{a}	290 ± 229
	2	1	1	5	3	0	87 ± 9	385 ± 183	574 ± 258^{a}
	2	2	1	4	4	0	71 ± 13	330 ± 177^{a}	460 ± 217
	0	0	1	1	6	1	72 ± 14	248 ± 157	381 ±184
Panavia F 2.0 [n = 40]	1	1	0	1	7	0	73 ± 16	225 ± 171	364 ± 164
	1	2	2	3	5	0	78 ± 12	219 ± 154^{b}	436 ± 241^{b}
	2	1	1	0	6	2	81 ± 12	250 ± 163	444 ± 231^{c}
	2	2	0	3	5	0	81 ± 8	404 ± 123^{b}	692 ± 165^{bc}
	0	0	1	0	7	1	73 ± 11	251 ± 193	489 ± 218

Cavity wall thickness (T), cavity wall depth (D), tooth cross-section area(CS), load at first damage (F1), fracture load (Fmax), failure modes: tooth fracture (A), core build-up failure (B), ceramic failure or decementation (C).
The same superscript letters show significant differences.

Load at first damage

Detailed results for test groups are given in Table 1 and Fig. 5a. A mean value in the KC-group was 265 ± 189 N and in the PF-group 270 ± 168 N. No influence was shown for the luting agents.

The ANCOVA analysis revealed a significant effect of cavity wall thickness (p = 0.001) on the results achieved. For teeth with a cavity wall depth of 2 mm

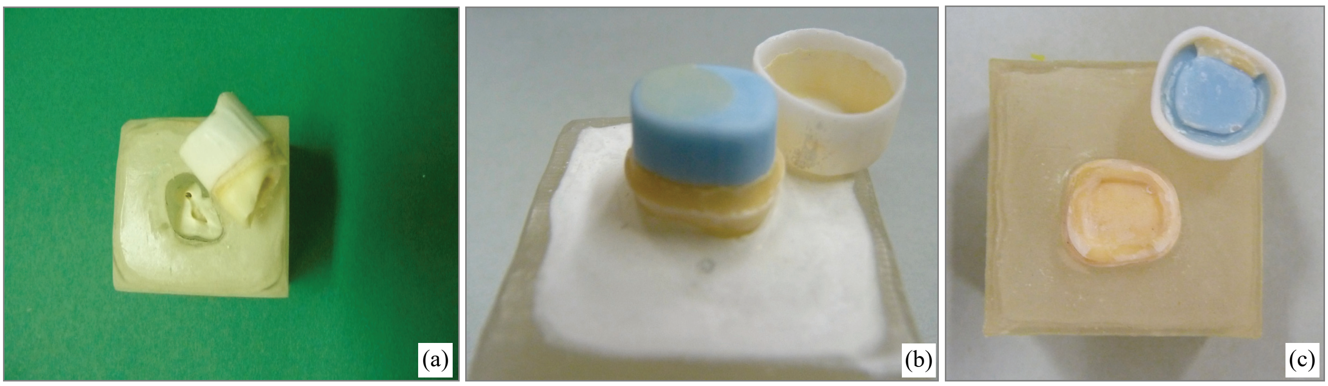

Fig. 4. Failure modes (representative): (a) tooth fracture, (b) decementation in PF-group, (c) core build-up and tooth fracture

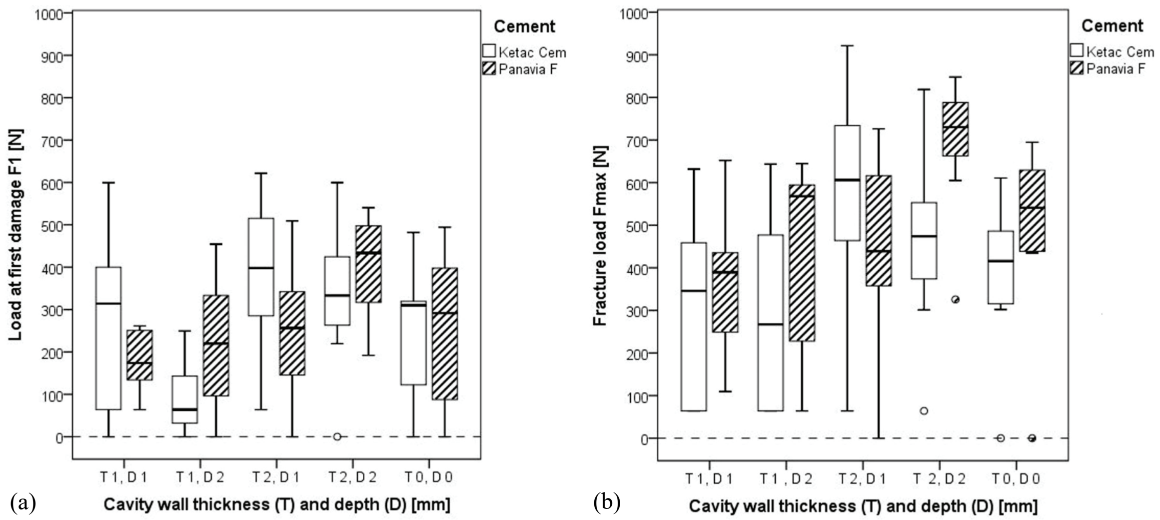

Fig. 5. Box and whisker plots for all groups with chewing simulation for (a) load at first damage, (b) fracture load

cemented with Ketac Cem or Panavia F 2.0, cavity wall thickness had a significant influence on the resistance to first damage (p = 0.003, p = 0.035, respectively). The resistance to first damage increased with increasing cavity wall thickness, i.e., the highest values were recorded for a wall thickness of 2 mm. Furthermore, no differences were shown between groups with retentive cavity and control groups without retentive cavity. First damage occurred, in general, at much lower loads than complete fracture. In most cases an opening of the marginal gap on the far side of the loaded cusp could be correlated to the load at first damage.

Fracture load

Detailed results are given in Table 1 and Fig. 5b. A mean value in the KC-group was 402 ± 235 N and in the PF-group 485 ± 226 N. As for load at first damage, no influence of luting agents was detected for the fracture load.

Cavity wall thickness had a significant influence on the resistance to fracture (ANCOVA, p = 0.001). In detail, the results increase with a cavity wall thickness of 2 mm for teeth with a cavity wall depth of 1 mm cemented with Ketac Cem (p = 0.01) as well as for teeth with a cavity wall depth of 2 mm cemented with Panavia F 2.0 (p = 0.02). Furthermore, for teeth with a cavity wall thickness of 2 mm cemented with Panavia F 2.0, cavity wall depth had a significant influence on the resistance to fracture (p = 0.02). No differences were shown compared to control group without retentive cavity.

Chewing simulation

The effect of the chewing simulation was examined on the identically prepared and conventionally cemented groups with a retentive cavity of 1 mm thickness and depth. In the control group without chewing simulation, the mean value for load at first damage was 327 ± 98 N and for the fracture load 550 ± 103 N. *T*-test showed no difference for the load at first damage where values decreased only slightly due to chewing simulation and significant differences for the fracture load (p = 0.02) where values decreased drastically by approximately 250 N due to chewing simulation.

4. Discussion

The null-hypothesis could not be rejected with exception for variable cavity wall thickness and tooth cross-section area.

Artificial ageing is recommended when testing ceramic and adhesive bond strength to simulate the oral environment [3], [2], [12]. Water storage of composite specimens results in the saturation with water. As a consequence, the amount of free radicals important for chemical reactions with new resin material decreases [18]. Therefore, when repairing composite material, the conditioning of the surface is recommended [18]. There is a lack of data for the conditioning of resin core build-up surfaces. Cotes et al. [3] recommends roughening the core build-up surface with a diamond bur before adhesive luting. This treatment showed the highest bond strength before thermocycling in vitro. However, no significant differences between the treated and untreated specimens were detected after artificial ageing [3].

In the present study, the specimens were stored in a thymol solution. Before cementation of the crowns, the core build-up surface was not roughened. This could result in lesser bond strength between core build-up and crowns [3], [4], [25], as the core build-up took up almost 2/3 of the bonding surface. This, on the other hand, could lead to lower loads at first damage and at fracture. The macroscopic analysis of decemented specimens showed that the cement remains almost only on the coping inert surfaces in the area of the core build-up. This can be interpreted as good adhesion of the cement to the ceramic surface. Furthermore, the often observed opening of the maginal gap on the tensile side when loaded with F1 indicated that either (partwise) debonding occurred between crown and build-up or tooth and build-up. Although samples could still be further loaded at this point, this damaging would be interpreted as clinical failure of the restoration by most dentists.

Zirconia ceramics have very good mechanical properties and are biocompatible [1], [13]. Glass-ionomer or adhesive resin cements are recommended for zirconia crowns. Clinical trials show that there are no differences between both cementation modes for full crowns [10], [20]. Likewise, in the current in vitro study, no differences between both cementation techniques were found. However, the fact that the samples were stored in a thymol solution must be taken into consideration, as this can affect the adhesive bond of resin cement or core build-ups [4], [25]. In macro- and microtensile bond strength tests MDP based resin cements tend to achieve the best results [15]. Furthermore, another publication recommends MDP luting agents for zirconia ceramics, especially for luting non-retentive restorations. [9]. However, these findings cannot be compared with the present study because of the incomparable study designs and complex sample constructions. Furthermore, Kern et al. [9] considers conventional retentive restorations (as used in the present study) to be unsuitable for testing the adhesive bond capacity of luting agents to ceramic.

Differing from the manufacturers' recommendations for cementation with Panavia F 2.0, the exposed dentin of the prepared teeth was etched with 35% phosphoric acid for 15 seconds. Turp et al. [28] showed in vitro that this procedure initially increased the bond strength of luting agents to dentin and resulted in thick hybrid layers, regular resin tags and no detached zones. Similar method (etching time 5 s [22]) was used in studies from Schmitter et al. [21], [22] and resulted in the highest values for Panavia F 2.0 groups, with which cast and alumina ceramic copings were cemented.

Schwindlig el al. [24] showed a very high fracture strength of 783 ± 118 N for zirconia crowns cemented with Ketac Cem and a cavity preparation of 2 mm depth and 2 mm width. In the present study, the highest resistance to first damage and fracture load was shown for the same retentive cavity design and Panavia F 2.0 cement (692 ± 165 N). Under this aspect, more importance must be given to the residual tooth structure before core build-up.

The most important advantage of an adhesive material is that no additional retention to tooth structure is needed [29]. Thus, the risks of clinical complications are minimized. Microtensile bond strength of adhesive systems to tooth structure is approved [29]. In the literature, retentive preparation for adhesive restorations is not recommended [29]. Retentive grooves and boxes for crown preparation are described as a method to maintain crown retention [7]. However, only a few studies exist regarding the usefulness of preparation techniques which increase the retention of adhesive core build-ups on severely destroyed vital teeth [16], [21], [22], [24]. Furthermore, none of these studies compare retentive boxes with completely non retentive flat preparation surfaces. The results of the present study showed no negative effect attributed to the absence of a retentive cavity on the load at first damage and fracture load of the test specimens. Load at first damage can be clinically interpreted as first failure (gap on a margin or decementation) which is associated with the need to renew the core/crown complex.

Schmitter et al. [22] described that non-axial forces are of higher importance for the core/crown complex when loading in in vitro studies than axial forces. Moreover, non-axial forces are lower than axial forces and more frequent during mastication [27]. Furthermore, maximal bite forces in vivo were measured at 398 ± 103 N [6]. Non-axial maximal forces capable of destroying natural teeth and crowned teeth in vitro were measured at 683 ± 166 N and 553 ± 218 N, respectively [21]. For loads at first damage there is a lack of comparable data. The minimum fracture load of crowned teeth without core build-up was recorded at 288 N without chewing simulation [21]. In the present study, both control groups without retentive box (cemented with Ketac Cem and Panavia F 2.0) showed mean values of fracture loads higher than 288 N. In comparison with the present study, Schmitter et al. [21] recommended a cavity depth of 2 mm in order to reach an appropriate retention of core build-up as well as fracture loads. In the current study, the cavity depth of 2 mm can be recommended in order to increase the fracture load, only for teeth cemented with Panavia F 2.0 and a retentive cavity with a wall thickness of 2 mm.

Furthermore, the resistance to first damage could also be increased in this group (from 250 ± 163 N to 404 ± 123 N). However, this increase was not statistically significant. Tooth/crown complex with a retentive cavity of 2 mm wall thickness and depth cemented with Panavia F 2.0 showed the highest registered values for a fracture load at 692 ± 165 N. Nevertheless, the preparation of the retentive cavity, especially with a 2 mm depth is related with higher risk of opening the pulp chamber and could compromise the vitality of the teeth. Furthermore, this study shows the lowest mean fracture load for the tooth/crown complex with a retentive cavity of 2 mm depth and 1 mm width cemented with Ketac Cem. For teeth with a 2 mm cavity depth a sufficient wall thickness of 2 mm is necessary to increase the resistance to first damage.

Nevertheless, it must be mentioned that the comparison of both studies is influenced by the lack of chewing simulation by Schmitter et al. [21]. In addition, the differences between in vitro studies in relation to the obtained results could also be affected by using human teeth when similar preparation designs with the same height and width as well as the same cementation techniques were employed. This can result in a high variance of data obtained [5]. However, it must be considered that for testing the adhesive bond to tooth structure there is no other acceptable material.

In the present study, human extracted teeth with closed pulp chamber were used to simulate vital teeth. However, the present in-vitro design did not reproduce the enzymatic degradation of the collagen matrix. This process can reduce the adhesive bond strength to dentin. In vivo, the hydrolytic degradation can influence the durability of adhesive restorations. For further applications inhibition of the enzymatic activity, e.g., with chlorhexidine should be considered [26].

These first in vitro results can be interpreted as follows: in horizontally fractured teeth the preparation of an additional artificial cavity to increase the retention of resin core build-up to tooth structure seems to be unnecessary. However, if a cavity already exists the wall thickness is of more importance than the depth. Nonetheless, further studies including more specimens and standardized tooth size are needed to confirm this conclusion.

In the present study, a significant influence of the tooth cross-section area was detected. Also, Rosentritt et al. [19] found a negative impact of small tooth diameter on the fracture strength. Further, Heintze [8] recommended dividing teeth into groups with comparable size, which can be affirmed.

5. Conclusions

Preparation of an additional retentive cavity seems to be unessential for increasing the build-up retention to tooth structure as well as resistance to fracture of single zirconia crowns. However, if a cavity already exists, the wall thickness is of more importance than the depth. Glass-ionomer cement as well as MDP modified adhesive cement can be used for cementation of zirconia crowns.

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