

Utjecaj raznih oblika mehaničke retencije na vezu polimernih materijala s metalnom podlogom

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Sažetak

Prigodom izradbe krunica i mostova koji se pokrivaju polimernim materijalom, osim problema određivanja boje nastaje i problem nedovoljno čvrstoga vezivanja polimera s metalnim skeletom.

Svrha je istraživanja utvrditi utjecaj mehaničke retencije i njezina razmaka, nanesenog opakera, postupka pjeskarenja, okoline i vremena, na spoj dvaju polimernih materijala s odgovarajućim metalnim uzorkom.

Vrijednosti retencijske čvrstoće spoja, istražuje se na osnovi opterećenja kada se mjesto spajanja odvojilo.

Retencija u obliku mikroperla daje bolju vezu od perla većega promjera. Opaker nije povećao adheziju polimera na metalnoj podlozi, a postupak pjeskarenja, vrsta polimernog materijala i vlažna pohrana nisu znatnije utjecali na promjenu retencijske čvrstoće.

Ključne riječi: polimerni materijal, metalni uzorak, retencijska čvrstoća

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Uvod

Pri izradbi krunica koje se prekrivaju polimernim materijalom javlja se osim, problema određivanja boje, i problem nedovoljno čvrstoga vezivanja akrilata s metalnim skeletom.

Polimerizacijom polimera nastala kontrakcija uzrokom je stvaranja mikroprostora između metala i akrilata te razvoja unutarnje napetosti. Porast granične pukotine rezultat je kontrakcije hlađenja, razlike u toplinskom koeficijentu širenja dvaju materijala, te spajanja materijala s različitim svojstvima i resorpcijom vode. Uz pomankanje kemijske veze

i adhezije na međuspoju, nastala pukotina može izazvati obojavanje, klimavost i konačan gubitak dijela fasete ili pak cijele fasete (1).

Objašnjenje za brzo starenje polimernih faseta treba tražiti u kakvoći sintetskih materijala, u tehnologiji postupka (razvojem polimerizacijskih tehnika koje zadovoljavaju parametre određene mjestom kasnije uporabe) i konsekvencijama spajanja dvaju materijala s različitim svojstvima (razvojem molekularnoga uravnotežujućeg intermedijarnog sloja).

Pošto se prepoznaju slabe točke na vezi između metalne podloge i polimernog materijala, jedan od

prvih uspjeha jesu poboljšanja adhezivnih svojstava metalne površine. Pri mehaničkom spajanju polimer se retinira na metalnu podlogu mehaničkim sredstvima (2-11) i/ili s pomoću agenasa za pričvršćivanje na osnovi kemijskog vezivanja (12-20).

Za pričvršćivanje se upotrebljavaju tri tipa adheziva: konvencionalni, BiS-GMA, i dvostruko afinitetni akrilati ("japanski akrilati"). Veza polimera ostvareno na osnovi Van der Waalsovih sila i hidrogen mosta, poboljšava se adhezivima koji osiguravaju jače jonsko vezivanje na metalu (21). No, većina agenasa za vezivanje ima dobru priljepljivost koja se smanjuje u vlažnoj okolini (22).

U zadnje vrijeme učinjeno je mnogo kako bi se našla veza bez međuprostora i visoka adhezija polimera s metalnom podlogom, a sve to zato da se eliminiira nerazmjer između trajanja metalne podloge te funkcionalne i estetske faze fasete (23-25).

Nastoji se pojednostaviti tehnika proizvodnje krunica i mostova te stvoriti što upotrebljivija retencijska površina. Istraživanjima se pokušava poboljšati veza na metalnoj podlozi, proširiti klinička primjena i pospješiti klinička svojstva, zatim prevladati nedostatke visokih troškova za kupnju skupih uređaja i eliminirati potencijalnu opasnost onečišćenosti osjetljive metalne površine.

Svrha istraživanja

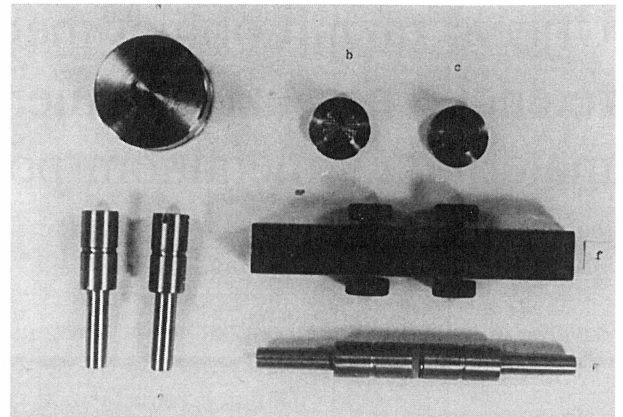
Svrha je istraživanja utvrditi utjecaj mehaničke retencije i njezina razmaka, nanosena opakera, postupka pjeskarenja, sredine i vremena na vezu dva-ju polimernih materijala (SR-Ivocron i SR-Isosit) s odgovarajućim metalnim uzorkom.

Materijal i postupak rada

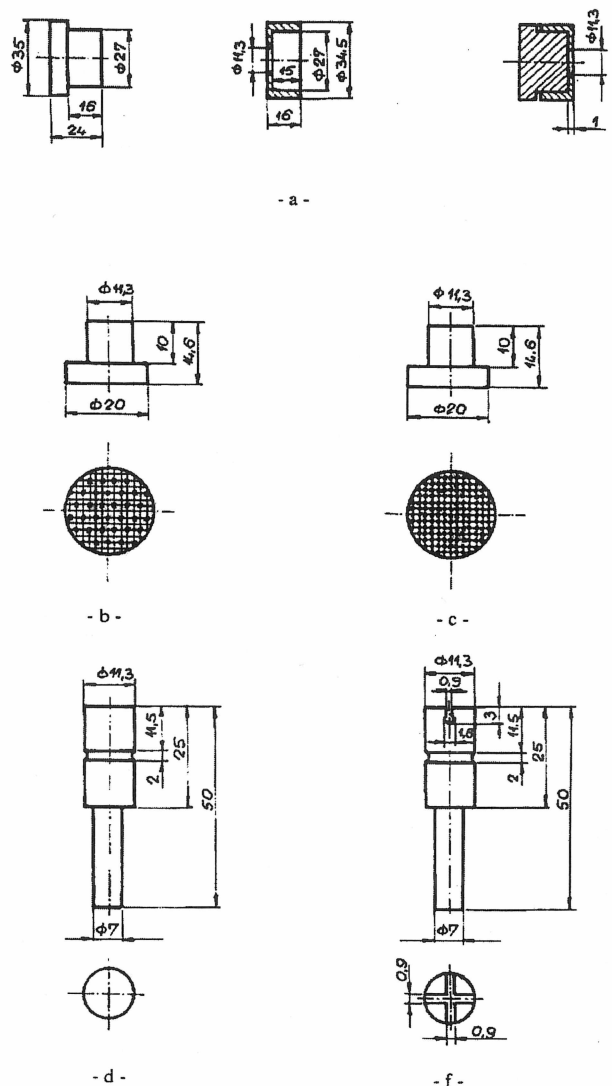
(1) Voštani uzorci

Metalni uzorci (400) dobiveni su na sljedeći način. Plavi inlejš vosak (Galenika - Zemun, SRJ) unosi se kapanjem u izbrušeni, polirani, kromirani metalni kalup, okruglog oblika promjera $d^2=11,3$ mm, kako bi se dobili potpuno jednaki uzorci (Slike 1 i 2-a).

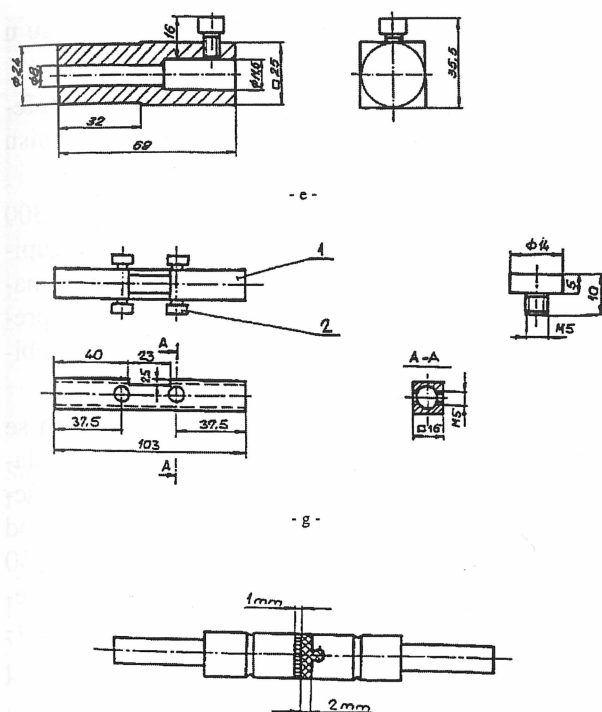
Pošto se vosak ohladi, na lice voštanih uzoraka nanese se mehaničke retencije različite veličine.



Slika 1. Prikaz alata upotrebjenog u studiji
Figure 1. Review of tools used in experiment



Slika 2. (nastavak str. 267)
Figure 2. (continuation page 267)



Slika 2. (a) Shema kalupa za dobivanje voštanih uzoraka; (b) Shema kalupa za dobivanje uzoraka s razmaknutim perlama; (c) Shema kalupa za dobivanje uzoraka sa zbijenim perlama; (d) Shema metalne drške I; (e) Shema sprave za dobivanje polimera u debljini od 2 mm; (f) Shema metalne drške II; (g) Shema kivete; (h) Shema epruvete

Figure 2. (a) Schematic diagram of the mold for producing wax patterns; (b) Schematic diagram of the mold for producing a spaced pattern of beads (macrobeads); (c) Schematic diagram of the mold for producing a spaced pattern of beads (microbeads); (d) Schematic diagram of the metal holder I; (e) Schematic diagram of the tool for producing a resin 2 mm thick; (f) Schematic diagram of the metal holder II; (g) Schematic diagram of the flask; (h) Schematic diagram of the test tube

pina bez pomoćne retencije (80 uzoraka), II. skupina s makroperla retencijom (160 uzoraka) i III. skupina s mikroperla retencijom (160 uzoraka).

Upotrebljena su dva različita razmaka između retencijskih perla:

(a) uzorak sa zbijenim perlama (24 perle) - perle se nasumice istresu, izravnavaju i izbroje u keramičkoj posudi, a na lice voštanog uzorka postavi se tanki sloj laka za retencijske perle Tako pripremljena voštana površina, pričvršćena na metalnoj spajalici, došla je u blag dodir s perlama u keramičkoj posudi, i

(b) uzorak s razmaknutim perlama (92 perle) - rabe se posebno pripremljeni okrugli metalni kalupi (Slike 1 i 2 - b i c), promjera $d^2=11,3$ mm, s nizom jamica (svaka je jamica udaljena jedna od druge 1 mm) koje su služile za smještaj perla u jedna-

Upotrebjene su dvije veličine retencijskih perla: retencijske perle najvećega promjera od 1 mm (Makroretencijske perle, Zlatarna Celje, Slovenija) i najmanjega promjera od 0,27 mm (Micro Retencionis, Ivoclar, Liechtenstein).

(2) Nanošnje retencijskih perla

Voštani su uzorci razvrstani u tri skupine, prema obliku upotrebjene retencije (Tablica 1): I sku-

Tablica 1. Raspored uzoraka u istraživanju

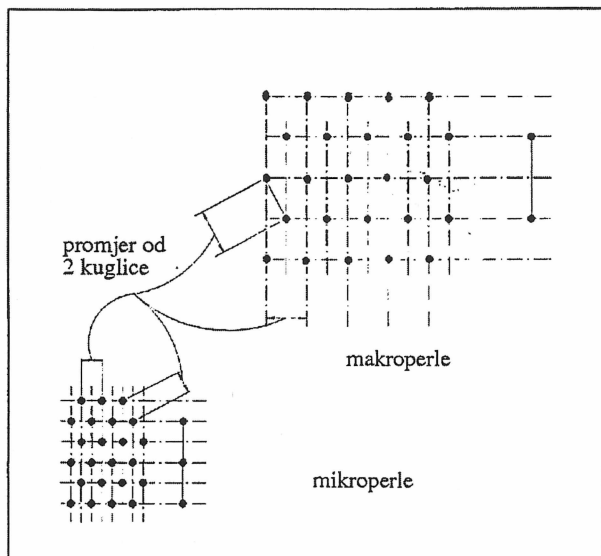
Table 1. Scheme of the patterns used in this investigation.

Uzorci Auropala prekriveni Ivocronom i Isositom	Vrsta mehaničke retencije																Ukupno				
	I				II								III								
	A	B	AB	K	A		B		AB		K		A		B			AB		K	
				A ₁	A ₂	B ₁	B ₂	AB ₁	AB ₂	K ₁	K ₂	A ₁	A ₂	B ₁	B ₂	AB ₁	AB ₂	K ₁	K ₂		
Testirani nakon 24 sata	10	10	10	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	200
Nakon 24 sata u vodi na 22 °C	10	10	10	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	200
Ukupno	20	20	20	20	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	400

I uzorak bez pomoćne retencije
 II uzorak s makroperla retencijom
 III uzorak s mikroperla retencijom
 A pjeskaren uzorak
 B uzorak premazan opakerom

AB uzorak pjeskaren i premazan opakerom
 K nema pripreme uzorka
 AB₁ uzorak sa zbijenim perlama
 AB₂ uzorak s razmaknutim perlama

kom razmaku (promjera dviju perla). Perle su u odgovarajuće jamice postavljene uz pomoć tanke zašiljene pincete (makroperle na svaku drugu jamicu) i oštroga metalnog instrumenta (mikroperla na svaku jamicu) (Slika 3). Nakon toga se je voštana površina uzorka premazala tankim slojem laka za retencijske perle, pričvrstila na metalnoj spajalici i dovela u blag dodir s perlama na kalupu. tablica 1



Slika 3. Perle postavljene u poziciju jednakog razmaka (dvije perle promjera).

Figure 3. Application of retentive beads in position at similar bead spacing (two bead diameter).

(3) Ulaganje i izlivanje

Tako dobiveni voštani uzorci stavljeni su u materijal za ulaganje Neoduroterm (Bayer, Leverkusen, Njemačka). Primijenjen je propisani odnos -30 grama vode i 100 grama praha, uz miješanje u vakuumskom aparatu Vakumat (Zlatarna Celje, Slovenija). Ulaganje je konvencionalno. Predgrijavanje i žarenje obavljeno je od 12 do 24 sata nakon ulaganja, a lijevanje u uređaju za centrifugalno lijevanje CF-2 (Zlatarna Celje, Slovenija) s neplemenitom Ag-Pd slitinom, Auopal S (Zlatarna Celje, Slovenija). Svaki je uzorak lijevan u posebnu cilindru za lijevanje i za sve uzorke upotrebljena je nova metalna slitina.

Metalni su uzorci zatim očišćeni metalnom četkom i acetonom te spojeni ljepilom (Tikso K-10 - jednokomponentni cijanoakrilatni adheziv), tako da su naličjem vezani za metalnu dršku I (Slika 1 i 2-d).

Tako pripremljeni metalni uzorci razvrstani su u dvije skupine:

(a) prva skupina - bez pripreme površine (referentni uzorak) (100 uzoraka), metalni uzorci nisu pjeskareni niti je na njih nanošen opaker, i

(b) druga skupina - s pripremom površine (300 uzoraka), metalne uzorke dijelimo na tri podskupine: A - uzorci pjeskareni (100), B - uzorci premazani opakerom (100), AB - uzorci pjeskareni i premazani opakerom (100). U oba polimera upotrijebi se je jednoslojni premaz istoga opakera.

Mehanička priprema površine pjeskarenjem se provedena je u uređaju za pjeskarenje PK-N (Zlatarna Celje, Slovenija) pod sljedećim uvjetima: tlačni kapacitet 0,4-0,6 MPa, na udaljenosti 5 mm od mlaznice, okomito na veznu površinu i tijekom 30 sekundi, s česticama aluminijeva oksida Al_2O_3 veličine 250 mikrona. Tako su pripremljeni samo uzorci predviđeni za pjeskarenje.

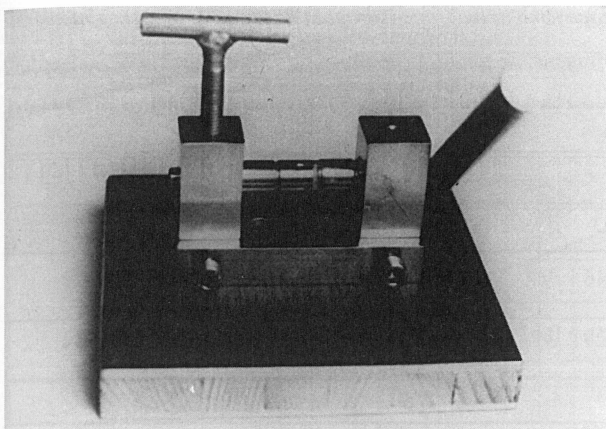
(4) Nanošenje polimernog materijala

Polimerni materijal nanošen je u debljini od 2 mm na metalnu dršku II (Slike 1 i 2 - e), koja ima odgovarajuću retenciju. Radi centriranja epruvete i polimerizacije čitav je postupak obavljen u odgovarajućoj kiveti (Slike 1 i 2 - f), gdje je prvo postavljena i fiksirana metalna drška I sa zalijepljenim metalnim uzorkom, a zatim metalna drška II s nanesenim polimerom. Kiveta, zajedno s drškama, postavljena je u uređaj Ivomat (Zlatarna Celje, Slovenija) za polimerizaciju (temperatura = 120 °C, tlak = 6 MPa, vrijeme = 6-7 minuta). Uvijek se radilo hladnom destiliranom vodom. Nakon završene polimerizacije višak polimernog materijala skidao se finim kamenom. Upotrijebljene su dvije vrste materijala za prekrivanje: SR-Ivocron-PE i SR-Isosit-N (Ivoclar-Lek, Slovenija).

Uzorci su se čuvali 24 sata u suhoj okolini. Da bi se ispitao utjecaj vlažne okoline na spoj polimernog materijala s metalnom podlogom uzorci su se pohranjivali u destiliranu vodu na temperaturi od 22 ± 2 °C.

(5) Testiranje prekida

Epruveta (Slike 1 i 2 - g) postavljena je u odgovarajuće otvore na spravi (Slika 4), gdje se jedan kraj učvrstio vijkom, a je na drugom je kraju poluga dužine deset centimetara, preko koje djeluje si-



Slika 4. Sprava za ispitivanje retencijske čvrstoće.
Figure 4. Jig for testing retentive strength.

la. Otpornost na torziju mjerena je na uređaju Universal-Prüfmaschine (Zwick 1439-DDR), a brzina kretanja sile koja odvaja polimer od metalne površine bila je 0,5 cm/mm.

Retencijska čvrstoća (čvrstoća spoja između polimernog materijala i metalnog uzorka), izrađena je vrijednošću opterećenja kada se mjesto spajanja odvojilo. Sila u njutnima, potrebna za prekid epruvete, registrirana je kao prekid na torzijski moment, a on se izračunavao na osnovu poznate površine uzorka, dužine poluge i sile.

- (1) $M_t = F \cdot l$ — moment torzije
 (2) $M_{tmax} = F_{max} \cdot l$ — maksimalni moment torzije pri kojem nastaje prekid

(3) $\sigma_{max} = \frac{M_{tmax} \cdot d/2}{I_p}$ — retencijska čvrstoća pri torzijskom momentu

(4) $I_p = \frac{\pi \cdot d^4}{32}$ — polarni moment inercije za kružni presjek

$$\sigma_{max} = \frac{M_{tmax} \cdot d/2}{I_p} = \frac{M_{tmax} \cdot d/2}{\frac{\pi \cdot d^4}{32}} = \frac{16 \cdot M_{tmax}}{\pi \cdot d^3}$$

(5) $\sigma_{max} = \frac{16 \cdot M_{tmax}}{\pi \cdot d^3}$ — retencijska čvrstoća pri torzijskom momentu za uzorak kružnog presjeka

$$\sigma_{max} = \frac{16 \cdot l \cdot F}{\pi \cdot d^3} = \frac{16 \cdot 10 \cdot F}{3,14 \cdot 1} = K \cdot F_{max} \text{ (N/cm}^2\text{)}$$

F = nepoznato (sila), l = 10 cm (dužina kraka poluge), d = 1 cm (promjer uzorka),

$$K = \frac{16 \cdot 10}{3,14 \cdot 1} = 51 \text{ (konstanta).}$$

Retencijska čvrstoća pri torzijskom momentu proporcionalna je sili, pa su se sve usporedbe mogle provoditi na osnovi samih vrijednosti sile.

(6) Statistička raščlamba

Rezultati mjerenja momenta torzije podvrgnuti su raščlambi varijance (jednosmjerna klasifikacija), kako bi se utvrdila postoje li statistički značajne razlike u retencijskoj čvrstoći između (a) sustava retencije, (b) vrste polimernog materijala, (c) sredine i vremena pohrane.

Rezultati

Rezultati istraživanja prikazani su tablično na osnovi statističke obrade podataka. Za spoj između Ivocrona i Auropala u Tablicama 2 do 4, a za spoj između Isosita i Auropala u Tablicama 5 do 7, prikazane su srednje vrijednosti i standardne devijacije retencijske čvrstoće pri torzijskom momentu (pogledati legendu).

U suhoj okolini na uzorcima bez pomoćne retencije (Tablica 2) srednje se vrijednosti retencijske čvrstoće za A (11,6), B (11,2), AB (11,1) i K (11,0) značajno ne razlikuju ($p > 0,05$). Najveća standardna devijacija za A zapaža se (0,78) uzorke. Kada se uzorci pohrane u destiliranu vodu na 22(20°C), vrijednosti retencijske čvrstoće znatno se ne mijenjaju ($p > 0,05$).

Srednje vrijednosti retencijske čvrstoće na uzorcima s makroperla retencijom (Tablica 3), za K (14,3 i 14,4) statistički je značajno veća od B (13,1 i 13,2) i u suhoj i u vlažnoj okolini ($p < 0,05$). Vlažna pohrana, pjeskarenje, te i raspored perla na uzorcima ne utječu znatno na vrijednost retencijske čvrstoće. Opažena je najveća standardna devijacija za A (1,02 i 1,29) i B1 (1,29) uzorke pohranjene u vlažnoj okolini.

Tablica 2. Srednje vrijednosti i standardne devijacije retencijske čvrstoće između Ivocrona Auropala u primjeni torzijskog momenta na uzorke bez pomoćne retencije

Table 2. The means and standard deviations of the retention strength between Ivocron and Auropal with torsion moment applied to patterns without an additional retention

Pohrana	Način obrade							
	A		B		AB		K	
	SV	SD	SV	SD	SV	SD	SV	SD
Suha 24 sata	11,6	0,78	11,2	0,46	11,1	0,36	11,0	0,29
Vlažna 24 sata	11,3	0,39	11,0	0,29	11,1	0,26	11,3	0,24
Statistika	NZR*		NZR*		NZR*		NZR*	

* nema značajne razlike

+ točke u istom okomitom stupcu označavaju varijable koje se ne razlikuju

I uzorak bez pomoćne retencije

A pjeskaren uzorak

B uzorak premazan opakerom

AB uzorak pjeskaren i premazan opakerom

K nema pripreme uzorka

I	Raščlamba varijance čvrstoće za vrstu pohrane ⁺					
	Suha pohrana			Vlažna pohrana		
	stupac 1	stupac 2	stupac 1	stupac 2	stupac 3	
A		0			0	
B	0				0	
AB	0				0	
K	0				0	

Tablica 3. Srednje vrijednosti i standardne devijacije retencijske čvrstoće između Ivocrona i Auropala u primjeni torzijskog momenta na uzorke makoperla retencijom

Table 3. The means and standard deviations of the retention strength between Ivocron and Auropal with torsion moment applied to patterns with macrobeads retention

Pohrana	Način obrade															
	A				B				AB				K			
	A ₁		A ₂		B ₁		B ₂		AB ₁		AB ₂		K ₁		K ₂	
	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD
Suha 24 sata	13,6	0,78	13,8	0,73	13,1	0,19	12,9	0,34	13,7	0,73	13,6	0,80	14,3	0,39	14,3	0,31
Vlažna 24 sata	13,5	1,02	13,5	1,29	13,0	0,97	13,2	0,24	13,6	0,34	13,5	0,62	14,3	0,52	14,4	0,82
Statistika	NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*	

* nema značajne razlike

+ točke u istom okomitom stupcu označavaju varijable koje se ne razlikuju

II uzorak s makoperla retencijom

A pjeskaren uzorak

B uzorak premazan opakerom

AB uzorak pjeskaren i premazan opakerom

K nema pripreme uzorka

AB₁ uzorak sa zbijenim perlama

AB₂ uzorak s razmaknutim perlama

II	Raščlamba varijance čvrstoće za vrstu pohrane ⁺					
	Suha pohrana			Vlažna pohrana		
	stupac 1	stupac 2	stupac 3	stupac 1	stupac 2	stupac 3
A ₁	0			0		
A ₂	0			0		
B ₁			0			0
B ₂			0			0
AB ₁	0			0		
AB ₂	0			0		
K ₁		0			0	
K ₂		0			0	

Tablica 4. Srednje vrijednosti i standardne devijacije retencijske čvrstoće između Ivocrona i Auropala u primjeni torzijskog momenta na uzorke mikroperla retencijom

Table 4. The means and standard deviations of the retention strength between Ivocron and Auropal with torsion moment applied to patterns with microbeads retention

Pohrana	Način obrade															
	A				B				AB				K			
	A ₁		A ₂		B ₁		B ₂		AB ₁		AB ₂		K ₁		K ₂	
	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD
Suha 24 sata	17,4	1,04	17,7	1,33	16,0	0,40	15,9	0,50	17,0	10,14	17,2	0,29	17,9	0,13	17,8	0,47
Vlažna	17,5	1,31	17,0	1,02	15,3	0,64	16,1	0,63	17,1	0,57	17,4	0,16	17,7	0,47	18,0	0,21
Statistika	NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*	

* nema značajne razlike

+ točke u istom okomitom stupcu označavaju varijable koje se ne razlikuju

II uzorak s makoperla retencijom

A pjeskaren uzorak

B uzorak premazan opakerom

AB uzorak pjeskaren i premazan opakerom

K nema pripreme uzorka

AB₁ uzorak sa zbijenim perlamaAB₂ uzorak s razmaknutim perlama

Raščlamba varijance čvrstoće za vrstu pohrane*						
II	Suha pohrana			Vlažna pohrana		
	stupac 1	stupac 2	stupac 3	stupac 1	stupac 2	stupac 3
A ₁	0			0		
A ₂	0			0		
B ₁			0			0
B ₂			0			0
AB ₁	0			0		
AB ₂	0			0		
K ₁		0			0	
K ₂		0			0	

Tablica 5. Srednje vrijednosti i standardne devijacije retencijske čvrstoće između Isosit-a i Auropala u primjene torzijskog momenta na uzorke bez pomoćne retencije

Table 5. The means and standard deviations of the retention strength between Isosit and Auropal with torsion moment applied to patterns without an additional retention

Pohrana	Način obrade							
	A		B		AB		K	
	SV	SD	SV	SD	SV	SD	SV	SD
Suha 24 sata	11,1	0,51	11,5	0,92	11,2	0,37	11,6	0,39
Vlažna 24 sata	11,2	0,59	11,6	1,06	11,1	0,38	11,3	0,28
Statistika	NZR*		NZR*		NZR*		NZR*	

* nema značajne razlike

+ točke u istom vertikalnom stupcu označavaju varijable koje se ne razlikuju

I uzorak bez pomoćne retencije

A pjeskaren uzorak

B uzorak premazan opakerom

AB uzorak pjeskaren i premazan opakerom

K nema pripreme uzorka

Raščlamba varijance čvrstoće za vrstu pohrane*			
I	Suha pohrana		Vlažna pohrana
	stupac 1	stupac 2	stupac 1
A	0	0	0
B	0	0	0
AB	0	0	0
K	0	0	0

Tablica 6. Srednje vrijednosti i standardne devijacije retencijske čvrstoće između Isosit-a i Auropala u primjeni torzijskog momenta na uzorke makroperla retencijom

Table 6. The means and standard deviations of the retention strength between Isosit and Auropal with torsion moment applied to patterns with macrobeads retention

Pohrana	Način obrade															
	A				B				AB				K			
	A ₁		A ₂		B ₁		B ₂		AB ₁		AB ₂		K ₁		K ₂	
	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD
Suha 24 sata	13,4	1,44	12,9	1,04	12,6	1,43	13,0	1,24	13,4	0,33	12,9	0,19	12,9	0,19	14,6	0,60
Vlažna	13,0	1,32	13,1	1,00	12,5	1,07	13,1	1,38	12,8	1,00	13,4	0,96	13,9	0,37	13,9	0,39
Statistika	NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*	

* nema značajne razlike

+ točke u istom vertikalnom stupcu označavaju varijable koje se ne razlikuju

II uzorak s makroperla retencijom

A pjeskaren uzorak

B uzorak premazan opakerom

AB uzorak pjeskaren i premazan opakerom

K nema pripreme uzorka

AB₁ uzorak sa zbijenim perlamaAB₂ uzorak s razmaknutim perlamaRaščlamba varijance čvrstoće za vrstu pohrane⁺

II	Suha pohrana			Vlažna pohrana		
	stupac 1	stupac 2	stupac 3		stupac 1	
A ₁	0				0	
A ₂	0				0	
B ₁	0				0	
B ₂	0				0	
AB ₁	0				0	
AB ₂	0				0	
K ₁			0		0	
K ₂		0			0	

Srednja vrijednost retencijske čvrstoće na uzorcima s mikroperla retencijom (Tablica 4) za K (17,9 i 18,0) značajno je veća od B (16,0 i 16,1) u suhoj i u vlažnoj okolini ($p < 0.05$). Vrijednost retencijske čvrstoće za A₁ (17,4 i 17,5), A₂ (17,7 i 17,0), AB₁ (17,0 i 17,1) i AB₂ (17,2 i 17,4) statistički su jednake. Zamjetna je najveća standardna devijacija za A (1,04) uzorke.

Srednje vrijednosti retencijske čvrstoće u skupini bez pomoćne retencije (Tablica 5). za A, B, AB i K u vlažnoj okolini (1,2 - 1,6) znatno se ne razlikuju ($p > 0,05$). Opaža se najveća standardna devijacija za B (0,92) i A (0,51) uzorke.

Kod retencije s makroperlama samo na uzorcima za K pohranjeni u suhoj okolini (Tablica 6), uzorak s razmaknutim perlama K₂ (14,6) daje statistički značajno veću srednju vrijednost retencijske čvrstoće u odnosu prema uzorku sa zbijenim perlama K₁ (12,9) ($p < 0.05$). Ostale vrijednosti retencijske čvrstoće statistički su jednake.

Srednje vrijednosti retencijske čvrstoće kod mikroperla retencije (Tablica 7), ne pokazuju statistički značajne razlike ni za jednu skupinu uzoraka ($p > 0.05$).

Rasprava

Za svaku fiksnu nadoknadu vrlo je važno kakvo je držanje fasete na metalnoj podlozi. Polimerom pokrivene krunice, nakon cementiranja u ustima, izložene su tlačnim silama koje su usporedne s osovinom zuba i zaustavljaju se s pomoću okluzalne ili incizalne metalne zaštite te silama smika i obrta koje djeluju na vestibularni dio polimernoga sloja kojim se opiru retencijski oblici krunica.

Pojava pukotine između polimera i metalne slitine (do 10 mikrona), te nedostatak retencijskih perla na marginalnome dijelu (gingivalni sulkus) smanjuju čvrstoću veze (1). U ovoj studiji veza je mehaničke naravi i ovisi od nekoliko čimbenika: veličini napanjanja na međuspoju, množini potkopanih mjesta

Tablica 7. Srednje vrijednosti i standardne devijacije retencijske čvrstoće između Isosit-a i Auropala u primjeni torzijskog momenta na uzorke mikropjerla retencijom

Table 7. The means and standard deviations of the retention strength between Isosit and Auropal with torsion moment applied to patterns with microbeads retention

Pohrana	Način obrade															
	A				B				AB				K			
	A ₁		A ₂		B ₁		B ₂		AB ₁		AB ₂		K ₁		K ₂	
	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD	SV	SD
Suha 24 sata	17,0	0,99	17,1	1,93	16,6	0,93	17,1	1,35	18,0	0,24	17,9	0,62	17,6	0,89	17,7	0,31
Vlažna	16,9	0,99	16,9	1,09	17,0	0,93	17,2	0,92	17,5	1,14	17,9	0,47	17,8	0,47	18,0	0,21
Statistika	NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*		NZR*	

* nema značajne razlike

+ točke u istom vertikalnom stupcu označavaju varijable koje se ne razlikuju

III uzorak s makoperla retencijom

A pjeskaren uzorak

B uzorak premazan opakero

AB uzorak pjeskaren i premazan opakero

K nema pripreme uzorka

AB₁ uzorak sa zbijenim perlamaAB₂ uzorak s razmaknutim perlama

Raščlamba varijance čvrstoće za vrstu pohrane*						
II	Suha pohrana			Vlažna pohrana		
		stupac 1			stupac 1	
A ₁		0			0	
A ₂		0			0	
B ₁		0			0	
B ₂		0			0	
AB ₁		0			0	
AB ₂		0			0	
K ₁		0			0	
K ₂		0			0	

na metalnoj slitini, i fizikalnim svojstvima materijala za pokrivanje.

Zna se da inkluzija metalnih kuglica u materijalu za pokrivanje uvjetuje nastanak koncentriranog naprezanja u opakero i polimeru što znatno smanjuje prekidnu čvrstoću (1).

Retencijska se je čvrstoća utvrđivala u odnosu prema količini potkopanih mjesta na metalnoj podlozi i veličini naprezanja na spoju između polimera i slitine. Pri visokom naprezanju na međuspoju je, i unatoč velikome broju potkopanih mjesta, potrebna mala sila da bi se polimer odvojio s metala. Kako bi se osigurala potrebna retencijska čvrstoća, potrebno je postići ravnotežu između tih dvaju čimbenika (26). Na osnovi dobivenih vrijednosti retencijske čvrstoće može si se reći da su uzorci s mikropjerla retencijom postigli tu ravnotežu.

U kliničkim okolnostima dolaze do izražaja fizikalne i kemijska svojstva polimernih materijala. Proizvodi na tržištu zadovoljavaju standarde suvremene protetike. Međutim, linijski koeficijent ek-

spanzije polimernih materijala nekoliko je puta veći od graničnih struktura (zuba i metalne slitine). Promjenom temperature za svaki stupanj razvija se pumpna akcija, zbog izmjene ekspanzije i kontrakcije materijala za pokrivanje, što slabi vezu na međuspoju (27).

Promatrajući poprečni presjek polimerom pokrivenog metalnog uzorka, mogu se razlikovati tri sloja sustava: (a) slitina, (b) opakero i (c) polimer. Prekid spoja pri torzijskome momentu nastaje na najslabijoj točki sustava.

U 85% slučajeva, na uzorcima pokrivenim Ivo-cronom nalen je čist prekid na metalu, sa potpunim odvajanjem opakera i polimera od metalne slitine, a u 15% slučajeva na uzorcima s razmaknutim perlama, nastao je prekid u polimeru s očitom opsežnom deformacijom polimera te mjestimice zadržanim opakero i akrilatom u potkopanim mjestima.

Čist prekid u polimeru (opakero se bolje veže za metalnu osnovu, nego polimer) nađen je u 80% slučajeva za AB, na uzorcima koji su pokriveni Isositom.

Usporedba između skupina s opakeraom i bez opakera (uzorci B i K), pokrivene Ivocronom, ide u korist skupina bez opakera. Retencijska čvrstoća u oba tipa retencije i u vlažnoj i u suhoj okolini bez opakera, znatno je veća od one s opakeraom. To se možda može objasniti činjenicom da je vjerojatno nanosen nešto deblji premaz opakera, što je smanjilo retencijski prostor perla i uvjetovalo manju retencijsku čvrstoću (28).

Opaker omogućuje maskiranje metalne pozadine i služi kao nezamjenjivo estetsko sredstvo, a kako je spoj polimer-metal posve mehaničke naravi, on se mora nanositi u što tanjem sloju. Na uzorcima pokrivenim Isositom nije pronaljen taj odnos između B i K, nego su opažene najveće standardne devijacije za B uzorke. Opaker-adheziv trebao je izazvati kemofizikalnu reakciju između oksida metala na površini metalnog uzorka i opakera. No, ona nije znatno povećala retencijsku čvrstoću.

Kod nanošenja adheziva često se do uključuje zrak između metalne površine i sloja vezivanja. Porastom temperature (polimerizacijom) volumen zraka se povećava i stvara mjehuriće u sloju veziva. Tako nastaju slaba mjesta u sustavu spoja (29).

Spoj opakera s metalnom slitinom bolji je od veze opakera s polimernim materijalom, vjerojatno zbog velike vrijednosti naprezanja koje se pomiče dalje od međuspoja (11), pa je i to moguće objašnjenje za nastanak prekida u polimeru na uzorcima pokrivenim Isositom.

Danas se samo može nagađati o procesima koji se događaju na pjeskarenoj površini. Činjenica je da se neki od aluminij oksida pijeska čvrsto ugrađuju u metalnu površinu i da se površinski sustav metalne slitine mijenja u odnosu prema početnom materijalu. Ta pojava nastaje zbog toplinskih učinaka lokalnoga zagrijavanja i reagirajuće moći karborundnoga pijeska na visokim temperaturama, sa pojednim komponentama metalne slitine.

Svrha je pjeskarenja je povećati geometrijsku površinu metalne slitine, očistiti je i aktivirati zatim, osigurati otpor silama smika usporedno s podlogom, te povećati svojstvo upijanja, a time i energije površine.

Promatrajući uzorke A koji su pjeskareni i zatim pokrivene Ivocronom i Isositom, može se zaključiti da se vrijednost retencijske čvrstoće znatno ne razlikuju, ali su zato opažene najveće standardne devijacije, što govori o nedosljednosti te tehnike.

Nije opažen utjecaj vlažnosti na spoj između polimera i metalne slitine, tj. ona nije imala znatan učinak na smanjenje retencijske čvrstoće u promatranom opservacijskom razdoblju.

U ovoj studiji vrijednosti retencijske čvrstoće kreću se u opsegu od 0,11 do 0,18 MPa (11 i 18 N/cm²) i većina prekida je na metalnoj podlozi. Upotrebljavala se je test metoda opterećenja na obrt, što je u suprotnosti s favoriziranim metodama naprezanja na smik, tlak i vlak. Kada se pogleda referentna literatura koja istražuje opterećenja polimera na mehaničkim sustavima retencije, nedvosmisleno se zaključuje da postoje razlike u rezultatima, od studije do studije. Nisu primjenjivani standardizirani uvjeti, metode rada, alat, debljina nanesenog adheziva i površina vezivanja, a javljaju se problemi centriranja epruvete i uzoraka u svim smjerovima.

Zaključak

Perle najmanjega promjera, bez obzira na to radi li se o zbijenim ili razmaknutim perlama daju bolju retenciju nego perle najvećega promjera. Opaker nije povećao adheziju polimera na metalnoj podlozi nego je, naprotiv, pri uporabi Ivocrona uvjetovao smanjenje retencijske čvrstoće i kod mikroperla i makroperla retencije. Pjeskarenje metalne površine ne preporučuje se kao retencijski sustav, zbog retencijske nedosljednosti. Vlažna pohrana i vrsta polimernoga materijala nisu znatno utjecali na promjenu retencijske čvrstoće.

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The Impact of Different Mechanical Retentive Designs on the Bond between Polymer Materials and Metal Framework

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Summary

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In addition to selecting an appropriate color, the problem of sufficiently strong bonding of the polymer layer to a metal cast also arises in processing crowns and bridges to be veneered.

The aim of this research was to determine the impact of the mechanical retention and its spacing, the opaquer applied, the method of sandblasting and the environment and time, on the bond between two polymer materials, with an appropriate metal pattern.

The study was carried out on 400 completely equal metal patterns divided into groups, exposed to water storage and stored in a dry environment. Values of bond strengths were tested in combinations of mechanical type bond with two polymer materials and two alloys.

The strength of the retention bond was computed on the basis of load values at the instant when the bond break occurred.

Minimum diameter beads give better retention than those of bigger diameter. The opaquer did not increase the adhesion between the polymer and material framework, whilst sandblasting of the metal surface, damp storage and type of polymer material, did not have a significant effect on retention strength.

Ključne riječi: polymer material, metal pattern, retention strength

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Introduction

On crowns which are covered with polymer material besides the problem of discolouring there is also the problem of insufficiently strong bonding of resin with the metal framework.

Polymerization of polymers created by shrinkage induces the formation of microspaces between the metal and resin and the development of internal strain. Enlargement of the marginal gap is the result of cooling contraction, differences of thermal coefficient of expansion of the two materials, and bonding of two materials with different properties

and water resorption. Along with the lack of chemical bond and adhesion on interface, the gap can cause discolouring, loosening and eventually loss of the whole veneer (1).

Explanation for the rapid wearing of polymer veneers needs to be sought in the quality of the synthetic materials and, technological processes (development of polymerization techniques in accordance with the parameters set by the location of subsequent use) and in the of binding of two materials with different properties (development of a molecularly balancing intermediate layer).

Having recognized the weak points on the bond between the metal framework and polymer material, one of the first steps is improvement of the adhesive properties of the metal surface.

At the mechanical bond polymer is retained on to the metallic foundation by mechanical means (2-11) and/or by the agent for attaching on to the base of the chemical bond (12-20).

Three types of adhesives are used for bonding, conventional resin, BiS-GMA resin and double affinity resin (Japanese resin). Improvement of bonding polymer is achieved on to the basis of Van der Waals's forces and a hydrogen bridge, improved with adhesives which ensure a stronger ionising bond on the metal (21). However, the majority of agents for bonding have good adhesion, which decreases in humid conditions (22).

Great efforts have recently been made to find a bond without interspaces and high adhesions of polymers with metal framework, all with the aim of eliminating the disproportion between the durability the metal framework and of the functional and aesthetic phase of the veneer (23-25).

The aim has been to simplify the technique in the production of crowns and bridges so as to create a more applicable retention surface. Research work has attempted to improve bonding on the metal framework, to expand clinical application and improve clinical features, to avoid high expenditure involved in the purchase of expensive devices and to eliminate the potential danger of contamination of the sensitive metal surface.

The Object of Research

The object of this study is to determine the effect of mechanical retention and its spacing, the applied opaquer, the process of sandblasting, environment and time on the bonding of two polymer materials (SR-Ivocron and SR-Isosit) with a corresponding metal pattern.

Material and Methodology of the Study

(1) Wax patterns

Metal samples (400) were prepared in the following way. Blue inlay wax (Galenika-Zemun, FRY)

was applied by dropping into a previously sharpened, polished chromium round metal, cast $d^2= 11.3$ mm in order to obtain exactly equal samples (Figures 1 and 2 - a).

After the wax was cooled, mechanical retention of different sizes was applied on the face of wax patterns. We used two different sizes of retention bead, the largest 1 mm diameter (Macroretention bead, Zlatarna Celje, Slovenia) and the smallest 0.27 mm diameter (Microretention, Ivoclar, Liechtenstein).

(2) Retentive bead application

Waxed patterns were classified into three groups, according to the form of applied retention (Table 1): group I. without additional retention (total of 80 patterns), group II. with macrobead retention (total of 160 patterns), and group III. with microbead retention (total of 160 patterns).

Two different spacings were applied between the beads.

(a) closely-packed pattern of beads (total of 24 beads) - beads are poured out evenly at random, and counted into a ceramic dish, while a thin layer of varnish for retention bead is applied to the surface of the wax pattern. This method of preparing the waxed surface, attached on the metal clip causes mild contact with beads in the ceramic dish, and

(b) patterns with spaced beads (total of 92) - a specially prepared round metallic cast is used (Figures 1 and 2 - b and c) diameter $d^2= 11.3$ mm, with a string of dimples (every dimple placed 1 mm from each other) which serves for placement of beads in the position of equal spacing (the diameter of two beads). The beads are positioned into appropriate dimples using thin pointed tweezers (macrobeads in every second dimple) and a sharp metal instrument (microbead in each dimple) (Figure 3). After which, the waxed surface of the pattern is varnished with a thin layer of lacquer for retentional beads, fastened on a metallic clip and brought into gentle contact with the beads on the cast.

(3) Investing and casting

The waxing patterns thus prepared are then placed into material investment Neoduroterm (Bayer Leverkusen, Germany). We used the prescribed ratio of 30 g of water and 100 g of powder by mixing

in the vacuum device Vacumat (Zlatarna Celje, Slovenia). The investment is conventional. Preheating and burning was performed within 12 to 24 hours after investing and casting into the device for centrifugal casting CF-2 (Zlatarna Celje, Slovenia) with non-precious Ag-Pd alloy Auropol S (Zlatarna Celje, Slovenia). Each pattern was invested into a separate casting ring for investing and a new alloy used for all patterns.

The metal patterns were later cleaned with a metal brush and acetone and then bonded together with glue (tikso K-10 - one component of cyano-acrylic adhesive), so that they are fixed to the metallic handle I along the back sides (Figures 1 and 2 - d).

The metal patterns are then classified into two groups:

(a) the first group - without a prepared surface (reference pattern) (100 patterns), metal patterns which had neither undergone sandblasting nor was covered with an application of opaquer, and

(b) the second group - with a prepared surface (300 patterns), metal patterns were divided into three subgroups: A - patterns sandblasted (100), B - patterns spread with opaquer (100), AB - patterns sandblasted and covered with opaquer (100). In both polymers a single layer spread with the same opaquer was used.

The mechanical preparation of the surface was performed in a device for sandblasting PK-N (Zlatarna Celje, Slovenia) under the following conditions: pressure capacity 0.4-0.6 MPa at a distance of 5 mm away from the nozzle, vertically on the bonding surface for 30 seconds, with aluminium oxide Al_2O_3 size of 250 microns. Only patterns intended for sandblasting were prepared in this way.

(4) Polymer application

The polymer material was applied 2 mm thick on the metal handle II (Figures 1 and 2 - e) which possesses appropriate retention. In order to line up the test tube and polymerization the whole procedure is carried out in appropriate flask (Figure 1 and 2 - f) where metal handle I was first placed and bonded to the metal pattern and after that the metal handle II with applied polymer. The flask, together with the handle, was placed into the device Ivomat (Zlatarna Celje, Slovenia) for polymerization (temperature = 120 °C, pressure = 6 MPa, time 6-7 minu-

tes). Cold and distilled water was always used. After polymerization the surplus polymer material was removed with fine stone. Two kinds of material for veneering were used: SR-Ivocron-PE and SR-Isosit-N (Ivoclar-Lek, Slovenia).

The patterns were kept for 24 hours in a dry environment. In order to investigate the effect of a humid environment on the compound of polymer material with metal framework, the patterns were kept in distilled water at a temperature of 22 ± 2 °C.

(5) Break test

The test tube (Figures 1 and 2 - g) was placed in appropriate openings on the device (Figure 4) where one end is attached to a screw the other to a lever 10 cm long, through which force was exerted.

The resistance to torsion was measured by the device Universal-Prüfmaschine (Zwick 1439-DDR), and the speed of force of movement which separates polymer from the metal surface was 0.5 cm/mm.

The retention strength (the strength of bonding between polymer material and metal pattern) was expressed through load when the place of connection is separated. The force in Newton's, necessary for the interruption of the test tube was registered as the interruption at the torque moment and estimated on the basis of the known pattern surface, the lever and force.

$$(1) \quad M_t = F \cdot l \quad \text{--- torque moment}$$

$$(2) \quad M_{t \max} = F_{\max} \cdot l \quad \text{--- maximal torque moment at which interruption occurs}$$

$$(3) \quad \sigma_{\max} = \frac{M_{t \max} \cdot d/2}{I_p} \quad \text{--- retention strength at torque moment}$$

$$(4) \quad I_p = \frac{\pi \cdot d^4}{32} \quad \text{--- polar moment of inertia for circle cutting}$$

$$\sigma_{\max} = \frac{M_{t \max} \cdot d/2}{I_p} = \frac{M_{t \max} \cdot d/2}{\frac{\pi \cdot d^4}{32}} = \frac{16 \cdot M_{t \max}}{\pi \cdot d^3}$$

$$(5) \quad \sigma_{\max} = \frac{16 \cdot M_{t \max}}{\pi \cdot d^3} \quad \text{--- retention strength at torque moment for pattern of circle cutting}$$

$$\sigma_{\max} = \frac{16 \cdot l \cdot F}{\pi \cdot d^3} = \frac{16 \cdot 10 \cdot F}{3,14 \cdot 1} =$$

$$= K \cdot F_{\max} \text{ (N/cm}^2\text{)}$$

F = unknown (force), l = 10 cm (length of lever), d = 1 cm (diameter of pattern),

$$K = \frac{16 \cdot 10}{3,14 \cdot 1} = 51 \text{ (constant).}$$

The retention strength by torque moment is in proportion to force and all comparisons can be performed on the basis of the values of force.

(6) Statistical analysis

The results of measurement of torque moment are proportional to force undergone for analysis of variance (one way classification) in order to confirm the existence of statistically significant differences in the retention strength between (a) system of retention, (b) type of polymer material, (c) environment and storage time.

Results

The results of the investigation are presented in tables and results statistically tested. For the compound of Ivocron and Auropal in Tables 2-4 and for the compound Isosit and Auropal in Tables 5-7, mean values and standard deviation of retention strength by torsion are presented (see legend).

Under dry conditions without supporting retention (Table 2), no significant differences were found ($p > 0.05$) among the mean values of retention strength for A (11.6), B (11.2), AB (11.1) and K (11.0). The highest standard deviation was noted for A (0.78) patterns. When the samples were stored in distilled water at a temperature 22 ± 2 °C, the values of retention strength were not significantly changed ($p > 0.05$).

Mean values of retention strength in patterns with macrobead retention (Table 3), for K (14.3 and 14.4) was statistically significantly higher in B (13.1 and 13.2) in dry and also in damp conditions ($p < 0.05$). Storage in damp conditions, sandblasting and spacing of beads in patterns, had no significant influence on the retention strength. The highest standard deviation was registered for A (1.02 and 1.29) and B₁ (1.29) of patterns stored in humid conditions.

Mean values of retention strength in patterns with microbead retention (Table 4), for K (17.9 and 18.0) was significantly higher than B (16.0 and 16.1) both in dry and humid conditions ($p < 0.05$). The values of retention strength for A₁ (17.4 and 17.5), A₂ (17.7 and 17.0), AB₁ (17.0 and 17.1) i AB₂ (17.2 and 17.4) were statistically equal. The highest standard deviation was noted for A (1.04) patterns.

Mean values of retention strength in the group without supplementing retention (Table 5), for A, B, AB and K in humid conditions (1.2 - 1.6) did not differ significantly ($p > 0.05$). The highest standard deviation was noted for B (0.92) and A (0.51) patterns.

At retention with macrobead only by K stored in dry conditions (Table 6), patterns with spaced pattern beads K₂ (14.6) gave statistically significantly higher medium value of retention strength in relation to the closely-packed pattern of beads K₁ (12.9) ($p < 0.05$). Other values of retention strength were statistically equal.

Mean values of retention strength by microbeads retention (Table 7) did not show statistically significant differences in any of the groups of patterns ($p > 0.05$).

Discussion

For every fixed replacement the amount of retention of veneer on the metal framework is of great importance. Crowns covered with polymer, after having been cemented in the mouth, are exposed to pressure forces which are parallel with the axis of the tooth and are prevented with the help of occlusal or incisal metal protection and forces of shear and torsion which work on the vestibular part of the polymer layer to which the retention form of crowns resisted.

The appearance of cracks between polymers and alloy (tillion micron) as well as the shortage of retention beads on marginal (gingival sulcus) decrease strengthening bond (1). In this study bonding is of a mechanical nature and depends on many factors: the size of strain on the interface, the amount of undermined places on the alloy and physical characteristics of the veneering material.

It is known that metallic bead inclusion in the material for covering induces the occurrence of con-

centrating exertion in opaquer and polymer which remarkably decreases the breaking strength (1).

The retention strength was established in the relation of quantity of undermined places on metal foundation and size of strain on bond between polymers and alloy. With a high strain on the interface and beside numerous undermined places, only a small force is necessary for the separation of polymer from metal. In order to ensure the necessary retention strength it is necessary to accomplish balance between these two factors (26). On the basis of obtained values of retention strength it can be said that patterns with microbead retention have achieved this balance.

In the clinical situation the physical and chemical properties of polymer material are pronounced. On the market products are presented which satisfy the standard of contemporary prosthetics. However, the linear coefficient of expansion of polymer material is several times higher than the bordering structure (tooth and alloy). With temperature changes, for every degree, due to exchange of expansion and contraction of material for cover, a pumping action develops which causes weakening of bonding on the interface (27).

By observing a diametrical section of a metal pattern covered with polymer one can differentiate three layers: (a) alloy, (b) opaquer and (c) polymer. Interruption of the bond at torsion moment appear on the weakest spot of the system.

In 85 percent of cases in patterns covered with Ivocron a clean break was found on the metal, with complete separation of opaquer and polymer from alloy. However, but in 15 percent of the cases of patterns with spaced pattern of bead, a break was found in polymer obvious extensive deformation of polymer and scattered retain opaquer and polymer in undermined places.

A clear break in polymer was found in 80 percent of cases for AB in patterns which are covered with Isosit (opaquer creates a better bond for metal framework than polymer).

Comparison between groups with and without opaquer (patterns B and K) covered with Ivocron demonstrates better quality without opaquer. Retention strength in both types in humid and in dry conditions without opaquer is considerably greater than that with opaquer. This can possibly be explained

by the fact that it occurred because a somewhat thicker layer of opaquer was applied, causing decreased retention space of beads and resulting in decreased retention strength (28).

Opaquer enables the masking of the metal background and serves as an irreplaceable aesthetic means, and since the compound of the polymer-metal bond is purely of a mechanical nature, it should therefore be applied in a thin layer. In patterns covered with Isosit this relation was not found between B and K, but the highest standard deviation was noted for B patterns. Opaquer-adhesive should induce a physical chemical reaction between oxide and metal on the surface of the metal pattern and opaquer. However, this did not significantly increase the retention strength.

When applying adhesives one of the problems often arising is the inclusion of air between the metal surface and bond layer. Higher temperature increases the volume of air and create bubbles in the connective layer. In this way weak places are produced in the system bond (29).

A compound of opaquer with alloy is better than a bond of opaquer with polymer material, possibly because of the great of strain which moves further from the interspace (11). Therefore this might be a possible explanation for the appearance of a break in polymer in the patterns covered with Isosit.

Today, one can only speculate about processes which develop on sandblasting surfaces. The fact is that several aluminium oxides of sand are strongly incorporated in the metal surface and the system of alloy changes in relation to the initial material. This phenomenon is caused by thermal effect of local heating and reacting forces of corundum sand at a high temperature with a component of alloy.

The role of sandblasting is to increase the geometrical surface of alloy, clean and activate the same, to ensure resistance forces shear parallel with foundation, as well as to increase the feature of wettability and, thus, also that of the surface energy.

Observing pattern A, after sandblasting and later being covered with Ivocron and Isosit, it can be concluded that the values of retention strength do not differ significantly, but. On the other hand, the highest standard deviations were noted here, which indicates the inconsistency of this technique.

The influence of humidity on the bond between the polymer and alloy were not observed, namely it did not have a significant effect on decreased retention strength during the observation period.

In this study the values of retention strength ranged from 0.11 to 0.18 MPa (11-18 N/cm²) and the majority of breaks were on the metal framework. Test for loading of torsion was used which is contrary to preferred methods of loading on shear, pressure and tensile. Based on reference literature on the strain of polymers on mechanical retention devices, it can be concluded that result differ from study to study. Standardised conditions were not used, neither were methods of study, tools, thickness of applied adhesives and surface of bond and problems which arose in centering test tubes and patterns in all directions.

Conclusion

Beads of the smallest diameter, regardless of whether closely-packed pattern of beads, or spaced pattern of beads, offer better retention than beads of the largest diameter.

Opaquer did not increase adhesion of polymers on the metal framework but, adversely, with Ivocron caused decreased retention strength both with micro and macro-bead retention.

Sandblasting of the metal surface is not generally recommended as a retention system, due to retentional inconsistency.

Humid storage and category of polymer material did not have any remarkable effects on the change of retention strength.