

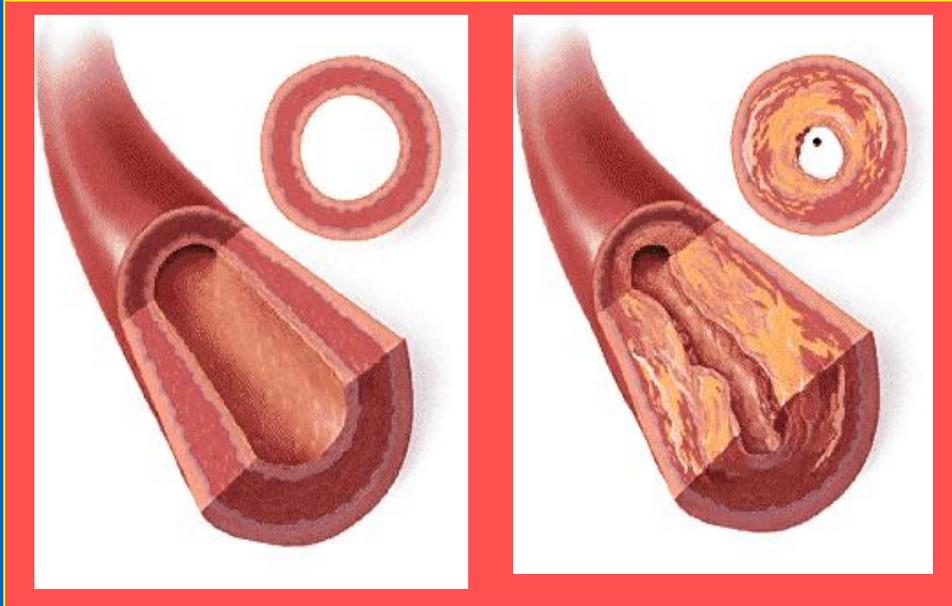
Seminario

Ottimizzazione del dispositivo stent coronarico al trattamento di restenosi intrastent

Carolina Ferrazzano

MALATTIE CARDIOVASCOLARI

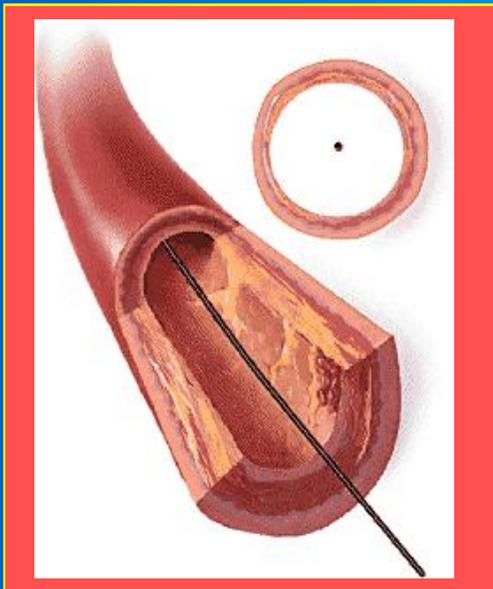
STENOSI CORONARICA



Occlusione del
lume vasale

By-pass
aortocoronarico

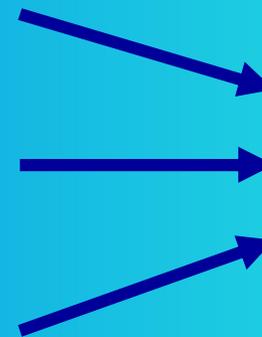
Angioplastica
PTCA



Elastic Recoil

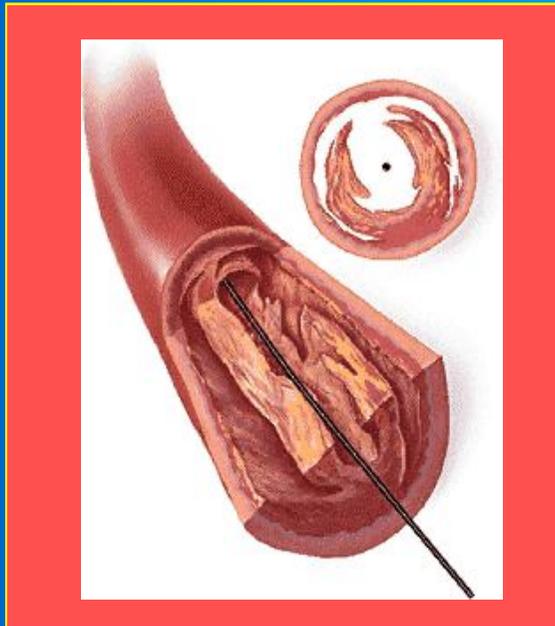
Rimodellamento
negativo

Iperplasia
neointimale



RESTENOSI

STENT CORONARI CI



STENT

- ❖ Elastic Recoil
- ❖ Rimodellamento negativo

I perplasia
neointimale

Formazione di neotessuto fra le maglie del
dispositivo legata:

- ✓ all'intrinseca trombogeneticità dello stent
- ✓ alla geometria delle maglie

Miglioramento bio-emocompatibilità

Ottimizzazione della geometria

Possibili
interventi

MIGLIORAMENTO
DELLA
BIO-EMOCOMPATIBILITÀ

STENT RIVESTITI

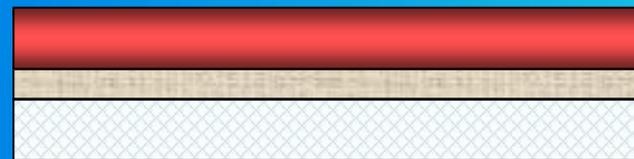
Intrinseca
trombogenicità
dello stent



bio ed emo-
compatibilità



STENT
RIVESTITI



Endotelio



Rivestimento



Stent metallico

Caratteristiche

- Ottima biocompatibilità
- Buona resistenza meccanica
- Efficacia di adesione

Limitazioni

- Rischio di restenosi intrastent
- Terapie farmacologiche

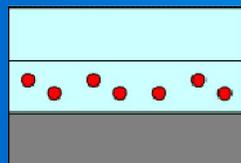
STENT A RILASCIO DI FARMACI (Drug Eluting Stent: DES)



Chypher stent

Cordis

Farmaco di rilascio: Sirolimus

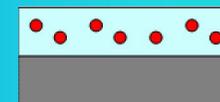


PBMA
Sirolimus/PEVA-PBMA
Stent

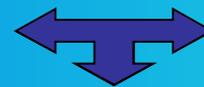
Taxus stent

Boston Scientific

Farmaco di rilascio: Paclitaxel

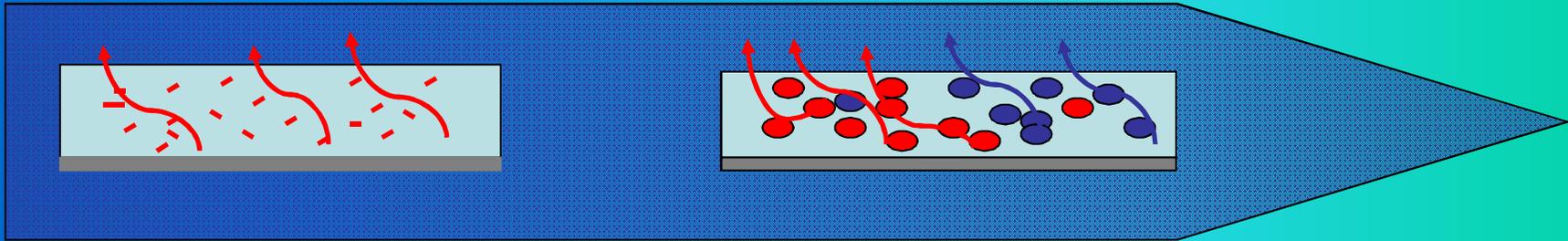


Paclitaxel/Translute
Stent



Rilascio per diffusione di un unico farmaco

RILASCIO MULTIFATTORIALE DI FARMACI



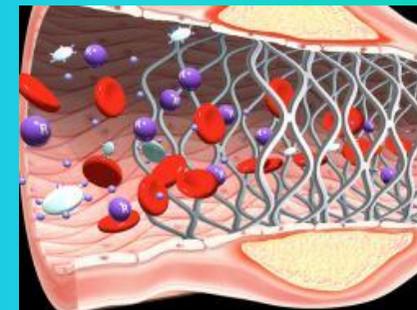
Sistema omogeneo

- Uniforme distribuzione del farmaco
- Farmaco sciolto nel polimero
- Rilascio controllato dalla diffusione

Sistema multi-componenti

- Rilascio multifattoriale
- Presenza di microparticelle
- Rilascio controllato da diffusione/degradazione

Rilascio di più agenti attivi, in simultanea o in sequenza, con cinetiche modulabili



OBIETTIVI

Realizzazione di un
rivestimento biocompatibile
per DES
(Drug Eluting stent)

- Adesione persistente

- Capace di inglobare
microsfere biodegradabili



Nebulizzazione



Immersione

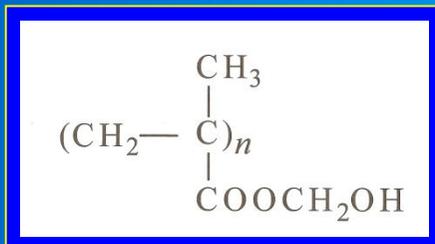
MATERIALI

- **PHEMA**
(poliidrossietilmetacrilato)



Rivestimento polimerico

- Idrogelo
- Eccellente biocompatibilità
- Buona resistenza meccanica



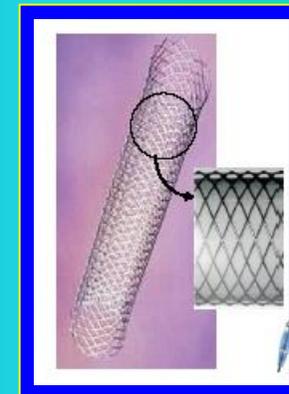
- **ACCIAIO AUSTENITICO**
316 L



Piattaforma metallica

- Ottima resistenza alla corrosione
- Ottime proprietà meccaniche

Sigma-Aldrich
cristalli polimerizzati
MW: 20,000 Da
Soluzione in etanolo al 10% w/v

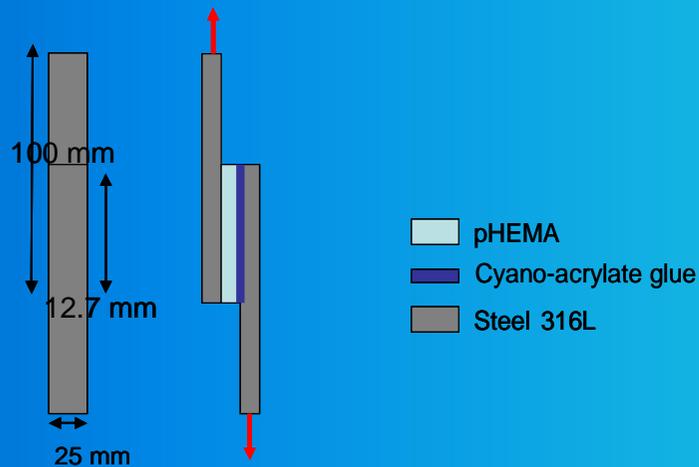


METODI

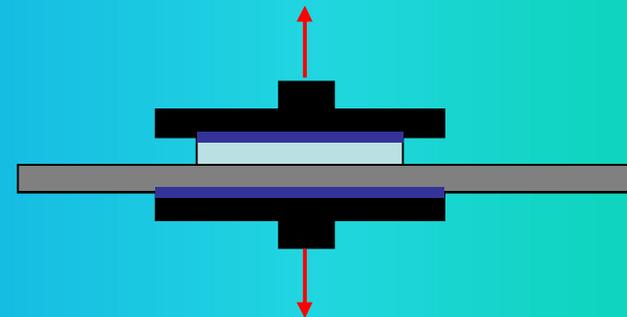
Prove di adesione NORMA ASTM D1002-05

cella di carico 1 KN
velocità di trazione 1,3 mm/min.

Prove di Shear (Single-Lap-Joint)



Prove di Pull-off



Tipologia campioni

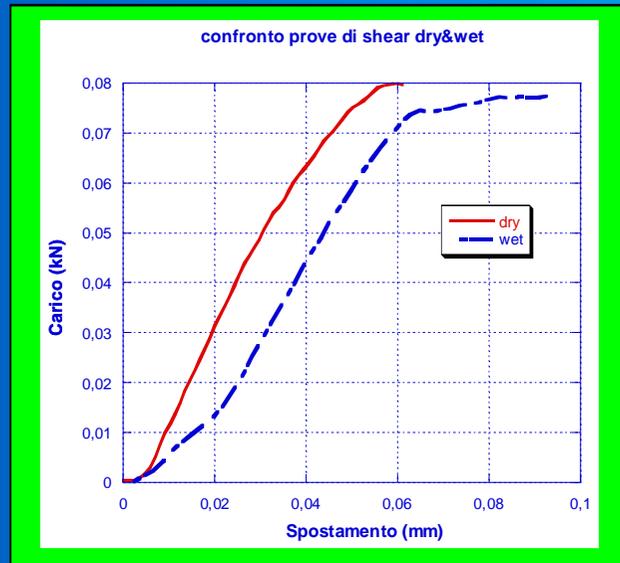
Idrogelo secco

Idrogelo stato swellato

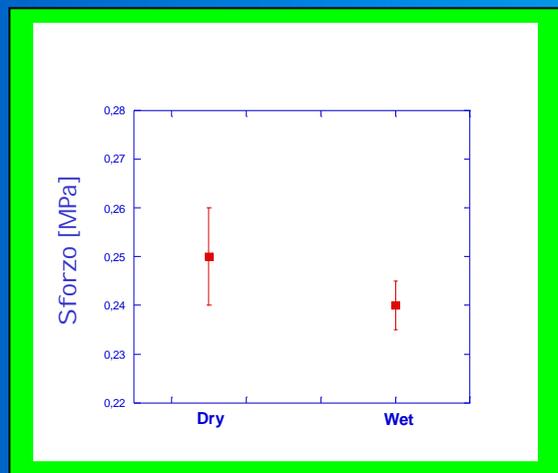
RISULTATI ADESIONE

Prove di Shear

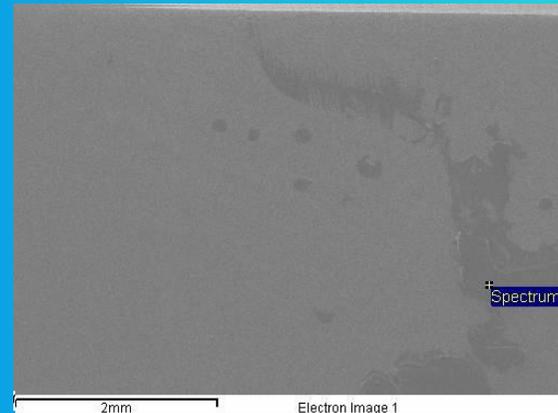
Curva carico-spostamento



Sforzo massimo



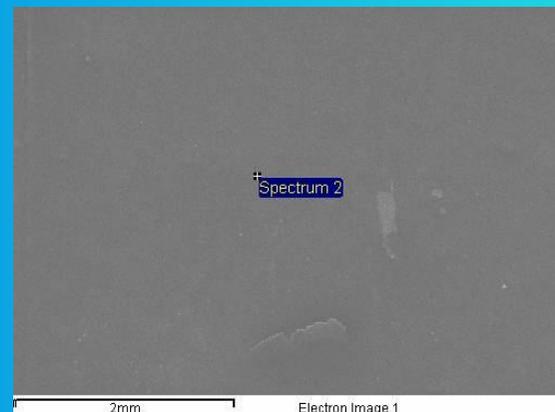
Faccia metallica rivestita



Element	Weight%	Atomic%
Cr K	17.91	18.98
Fe K	82.09	81.02

Element	Weight%	Atomic%
C K	67.35	73.31
O K	32.65	26.69

Faccia metallica non rivestita



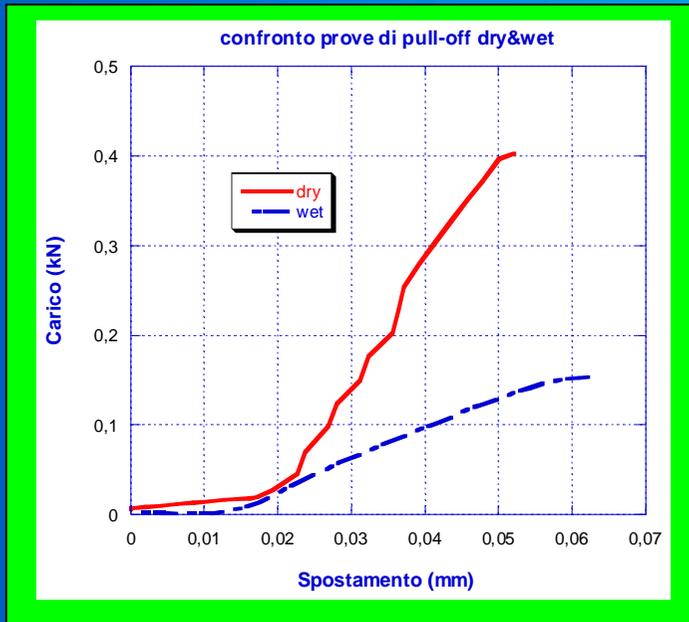
Element	Weight%	Atomic%
Cr K	16.64	17.65
Fe K	83.36	82.35

Element	Weight%	Atomic%
C K	77.77	82.33
O K	22.23	17.67

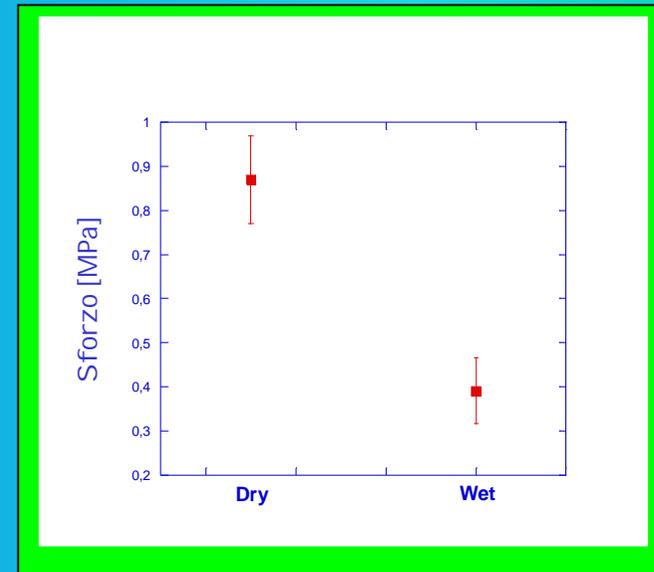
RISULTATI ADESIONE

Prove di Pull-off

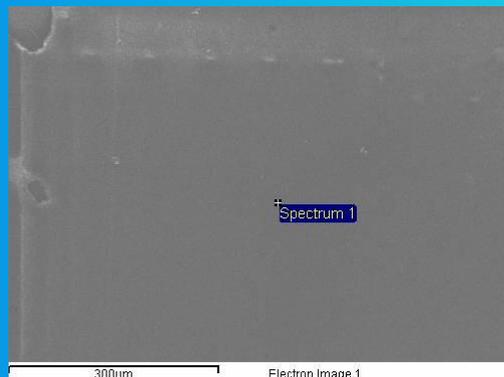
Curva carico-spostamento



Sforzo massimo



Faccia metallica rivestita



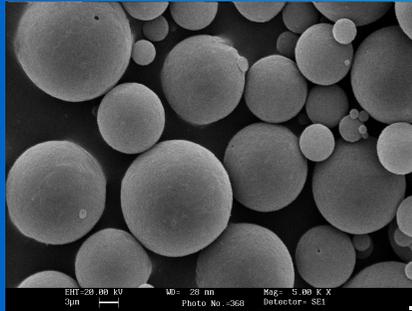
Element	Weight%	Atomic%
Cr K	16.64	17.65
Fe K	83.36	82.35

MATERIALI

- **μ-SFERE di PLGA**
(acido polilattico-co-glicolico)

→ 50:50

Acido polilattico
+
Acido poliglicolico



- Polimero biocompatibile e biodegradabile
- Modulazione-tempo degradazione
- Versatilità formulativa

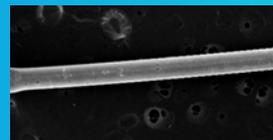
- **PHEMA**
(poliidrossietilmetacrilato)

→ Soluzione 10% w/v in etanolo

→ Soluzione 30% w/v in etanolo

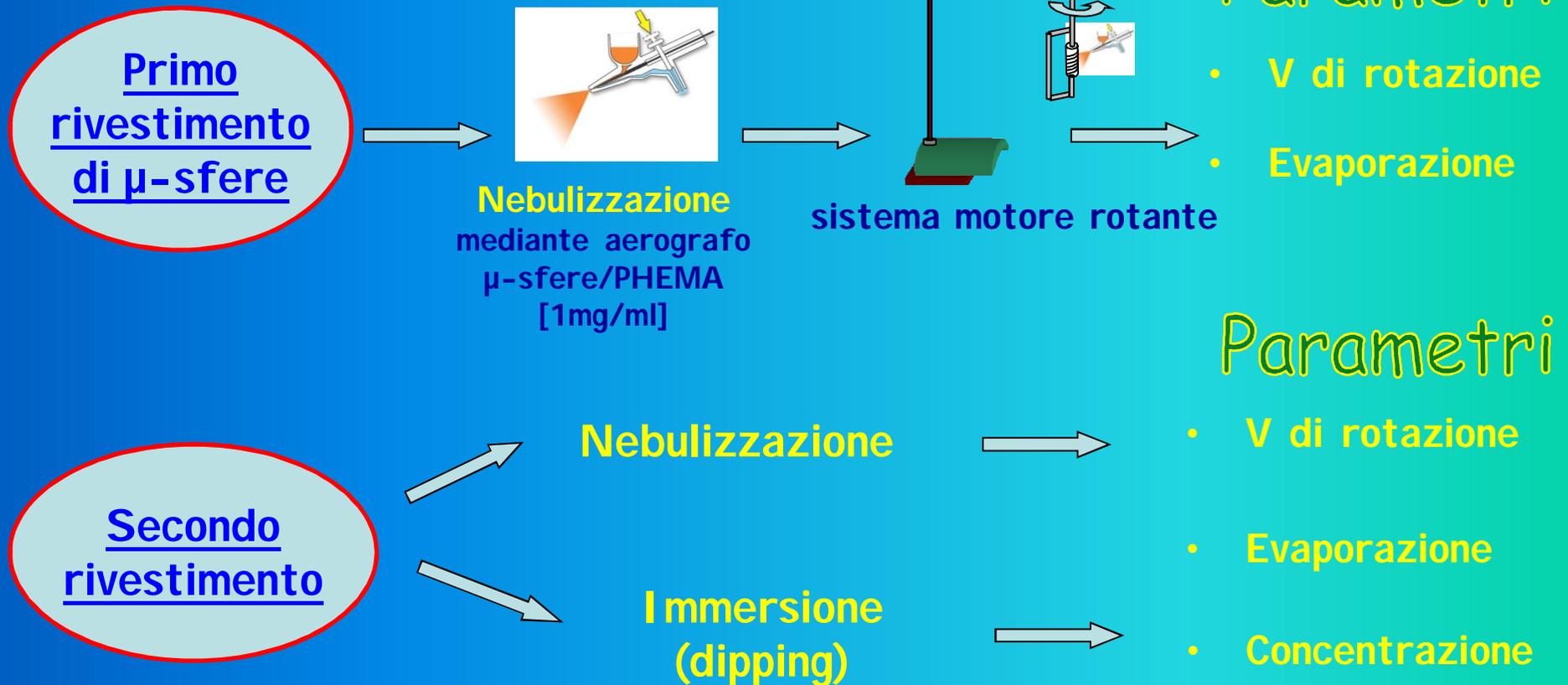
→ Soluzione 40% w/v in etanolo

- **Fili di acciaio austenitico 316L**



METODI

Tecnica per rivestimento



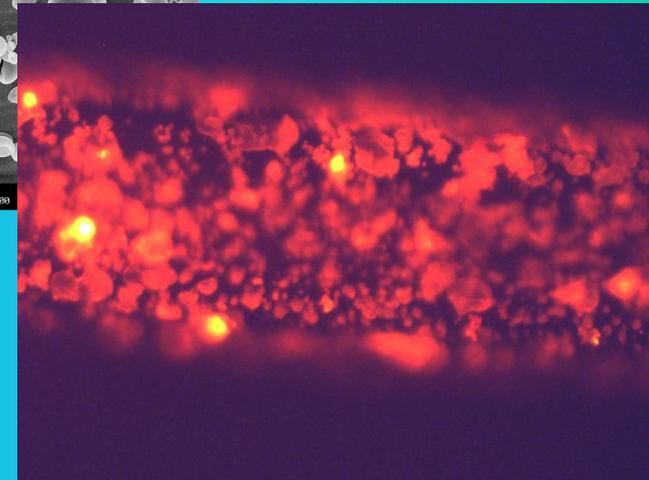
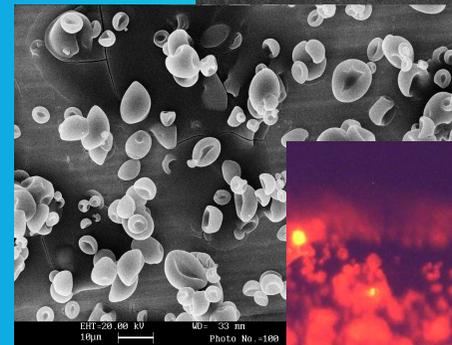
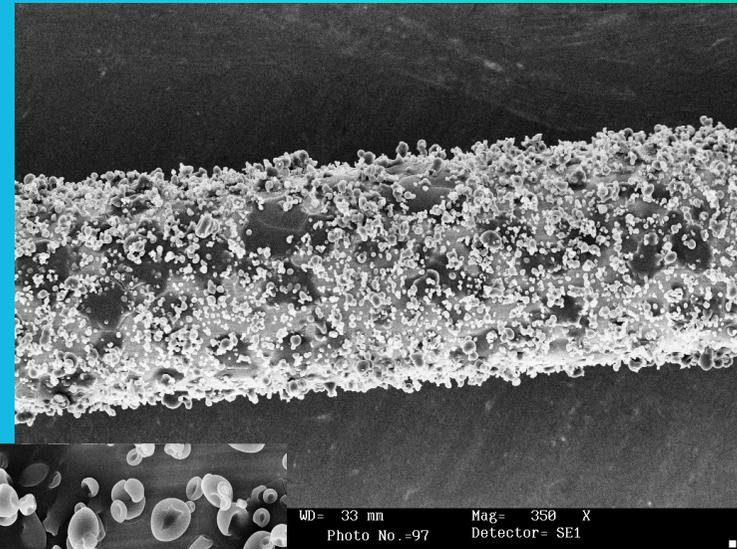
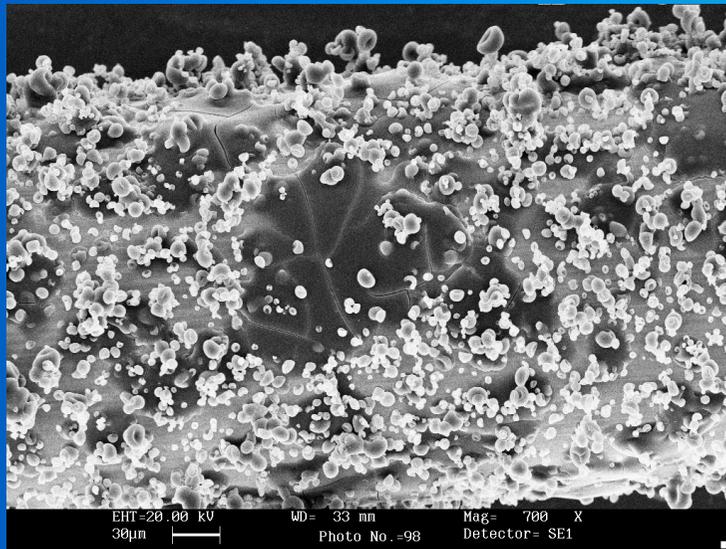
Variando opportunamente i parametri di processo è possibile modulare lo spessore del rivestimento

RISULTATI

Primo rivestimento

Realizzazione
layer di μ -sfere

- V: 6rpm
- Evaporazione: lenta
- Concentrazione: 10% w/v



Presenza delle μ -sfere sulla superficie del campione

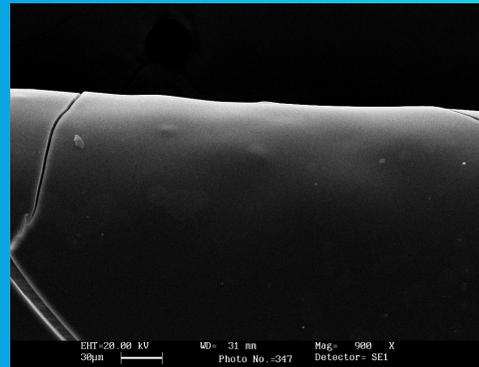
RISULTATI

Secondo rivestimento

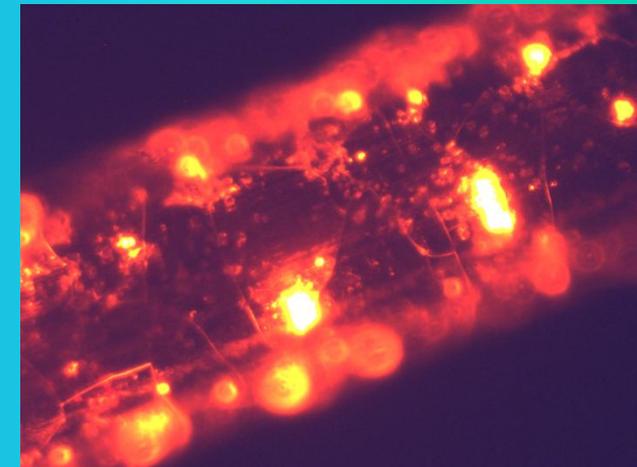
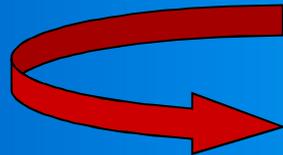
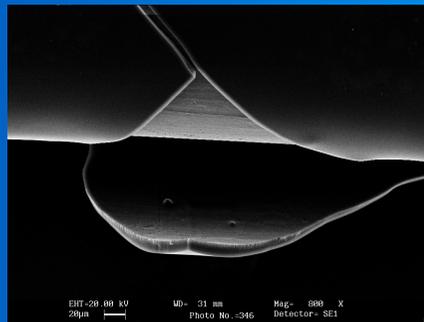
Nebulizzazione

- **V: 6rpm**
- **Evaporazione: aria**
- **Concentrazione: 10% w/v**

Osservazione ESEM



Superficie liscia ed omogenea

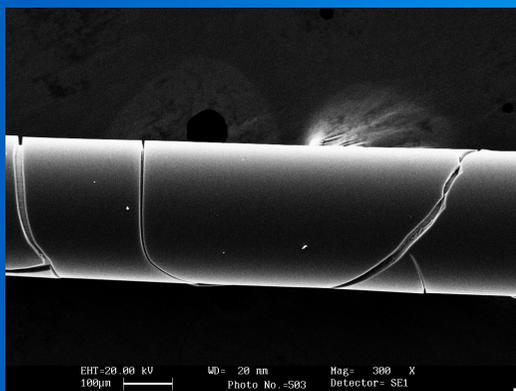


Presenza delle μ -sfere all'interno del rivestimento

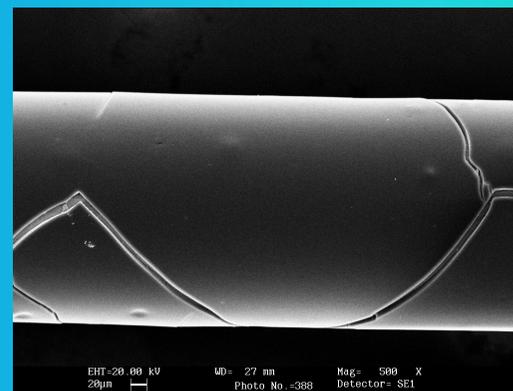
RIULTATI

Ottimizzazione parametri per DIPPING

- **Concentrazione: 30% w/v**

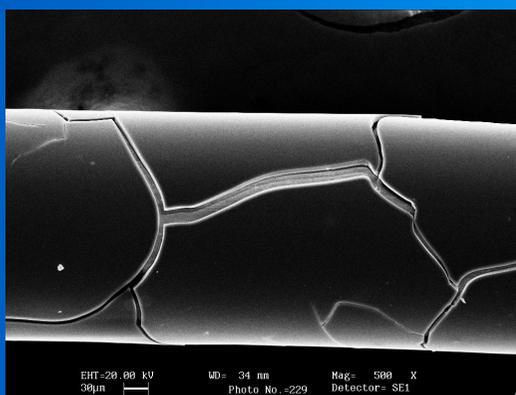


Spessore ~ 7 μ m



Spessore
variabile

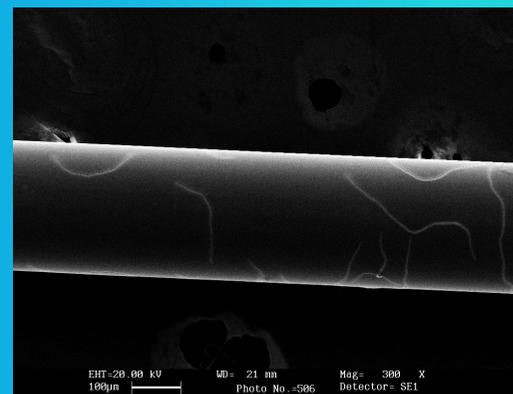
- **Evaporazione: aria**



Spessore
variabile

- **Evaporazione: lenta**

- **Evaporazione: sotto cappa**



Spessore ridotto
~ 1 μ m

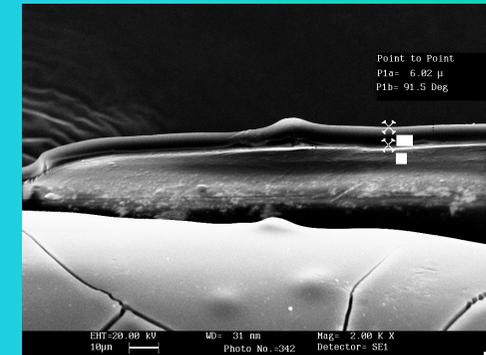
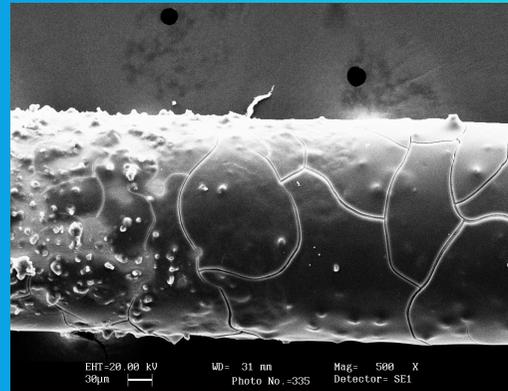
- **Evaporazione: in rotazione**

RI SULTATI

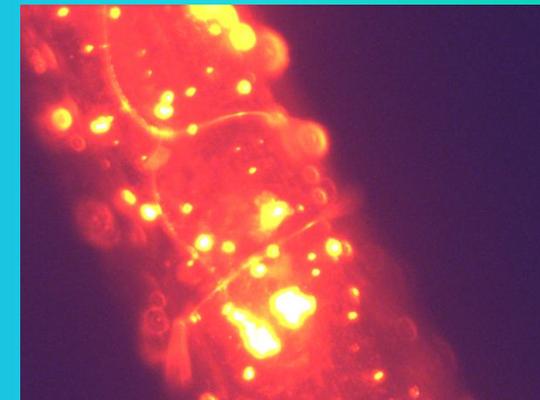
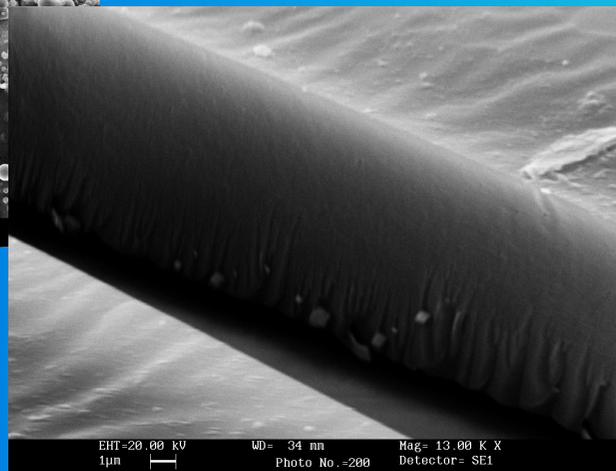
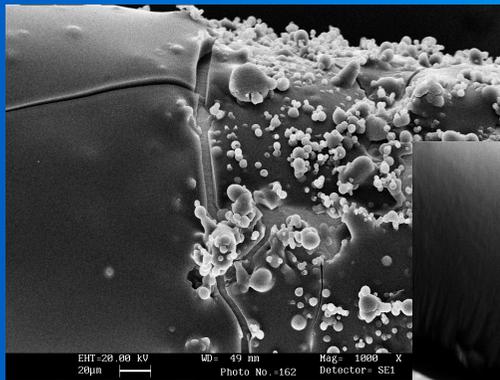
Secondo rivestimento

DIPPING

- Concentrazione: 30% w/v
- Evaporazione: aria



Superficie liscia ed omogenea

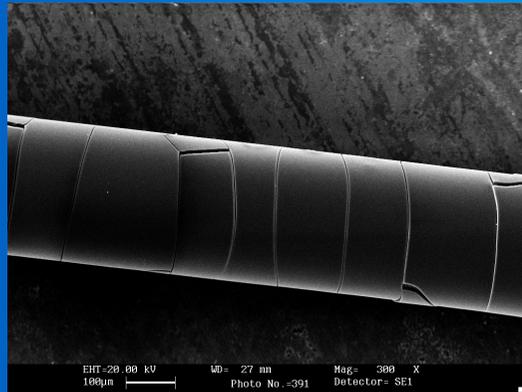


Presenza delle μ -sfere all'interno del rivestimento

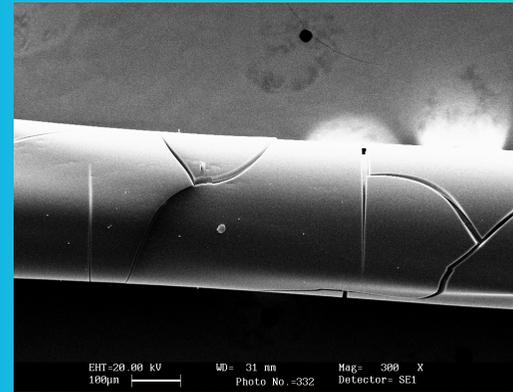
RIULTATI

Ottimizzazione parametri per DIPPING

- Concentrazione: 40% w/v

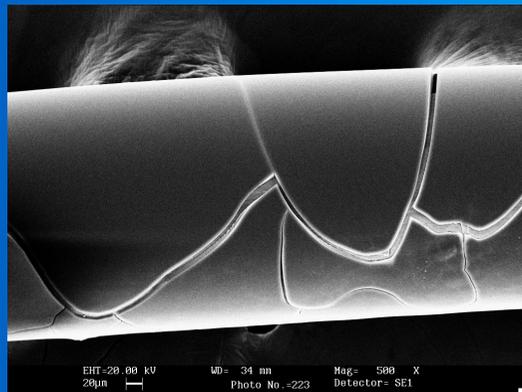


Spessore ~ 10 µm



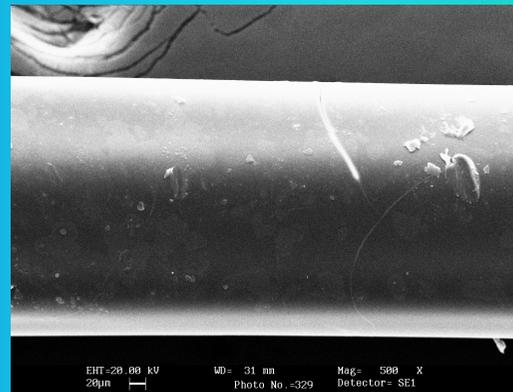
Spessore variabile

- Evaporazione: aria



Spessore variabile

- Evaporazione: sotto cappa



Spessore ridotto ~ 4µm

- Evaporazione: lenta

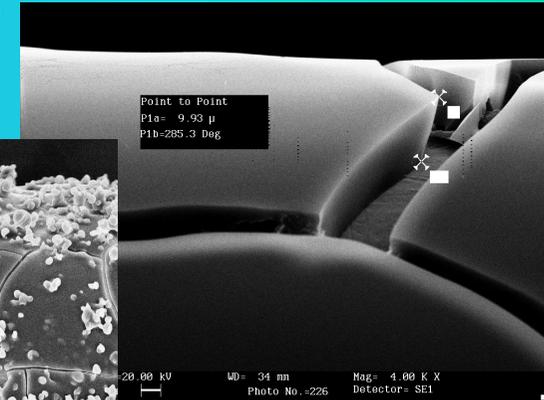
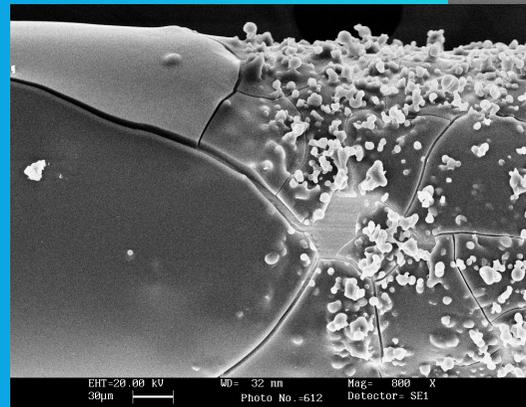
- Evaporazione: in rotazione

RISULTATI

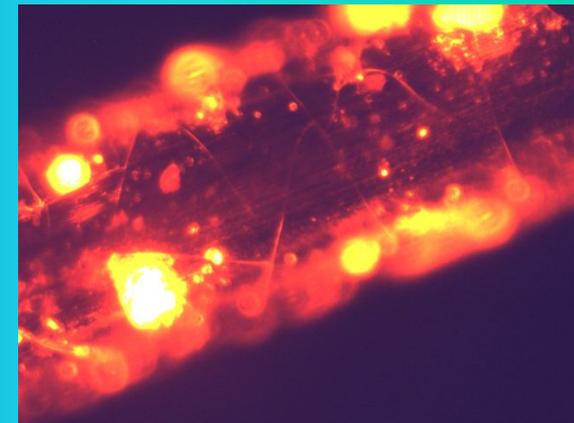
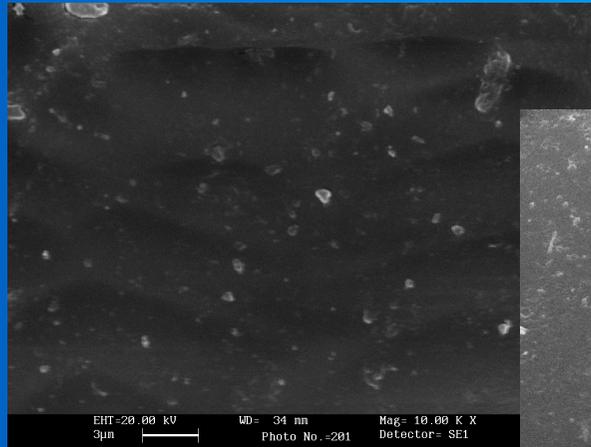
Secondo rivestimento

DIPPING

- Concentrazione: 40% w/v
- Evaporazione: aria



Superficie liscia ed omogenea



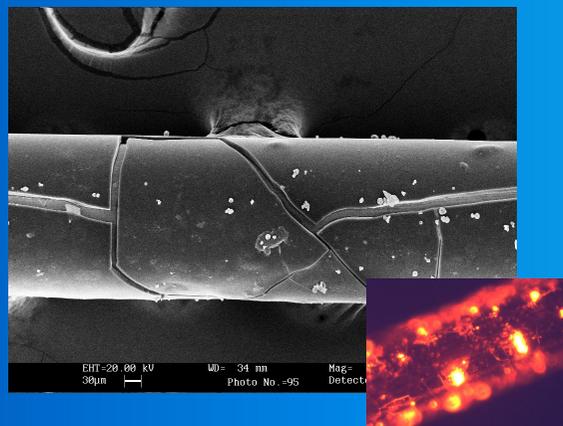
Presenza delle μ -sfere all'interno del rivestimento

CONCLUSIONI RIVESTIMENTO

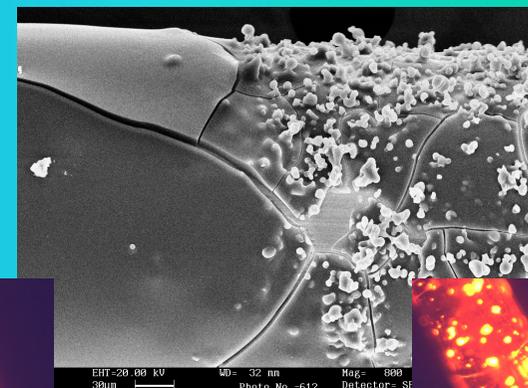
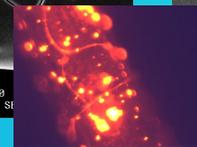
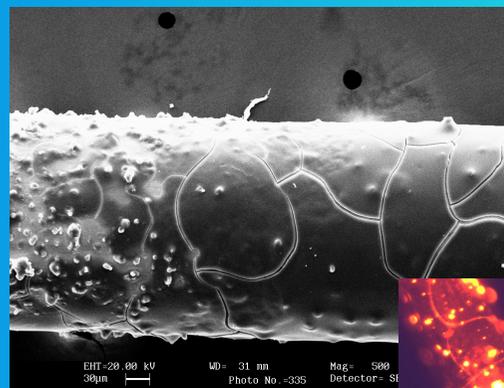
Realizzazione di un rivestimento polimerico capace di aderire in maniera persistente alla piattaforma sopportando i carichi a cui è sottoposto lo stent

Realizzazione di un rivestimento liscio ed uniforme capace di inglobare microsferine

NEBULIZZAZIONE



DIPPING 30% (40%) w/v



SVILUPPI

- Inglobare microsfere a differente formulazione di PLGA per il rilascio multifattoriale
- Verificare l'efficacia del sistema multicomponente in vivo attraverso l'utilizzo di sistemi computazionali simulando il comportamento in ambienti altamente complessi quali il corpo umano

OTTIMIZZAZIONE DELLA GEOMETRIA

Stent di uso clinico

***Palmaz-Schatz
BEIS***



- Buona resistenza alla compressione
- Ottimo "effetto impalcatura"
- Alta forza radiale dopo l'espansione
- Scarsa flessibilità longitudinale

Cordis Johnson & Johnson

"Versione articolata"

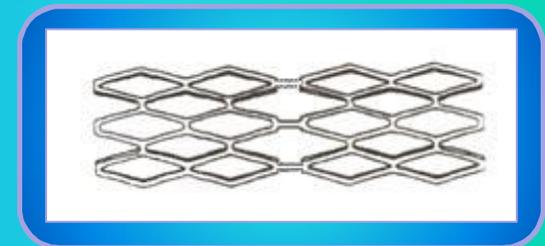
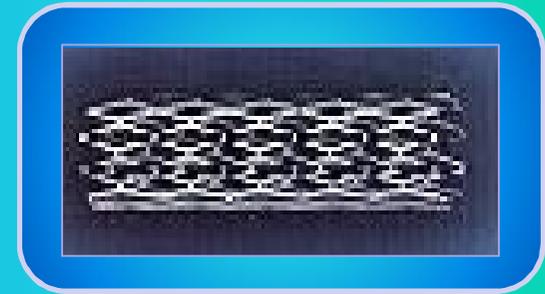


***Palmaz-Schatz
ABEIS***



Versione articolata:
migliore manovrabilità

Cordis Johnson & Johnson



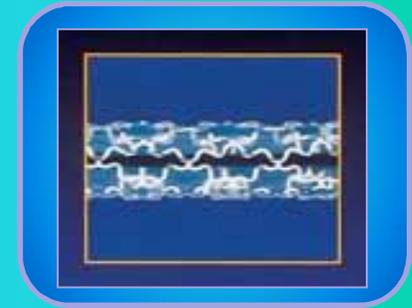
Stent di uso clinico

*Palmaz-Schatz
Crown*

Cordis Johnson & Johnson



- Stesse caratteristiche ottimali del P-S BEIS
- Migliore flessibilità longitudinale
- Privo di articolazione
- Giunzioni ottimali tra le maglie

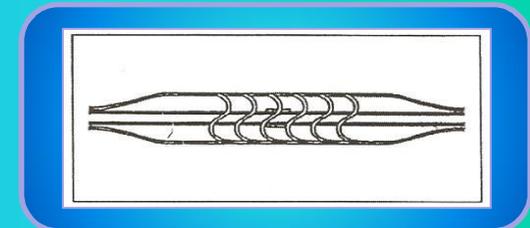


*Coronary
Cardiocoil*

Cordis Johnson & Johnson



- Alta flessibilità
- Buona forza radiale
- **AUTOESPANDIBILE**: graduale espansione → riduzione del danno endoteliale; sovra-sottodimensionamenti del diametro finale



Stent di uso clinico

Joflex stent

JOMED



- Stesse caratteristiche ottimali del P-S BEIS
- Ottima flessibilità longitudinale
- Privo di articolazione
- Giunzioni ottimali tra le maglie

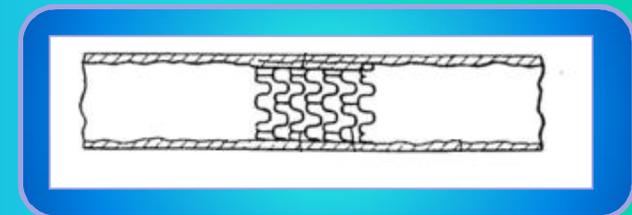


NIR stent

**Boston Scientific
SCIMED**



- Ottima flessibilità durante il posizionamento
- Alta forza radiale dopo l'espansione
- Supporto continuo: senza articolazioni o tratti di maglia tra loro scollegati → adeguata distribuzione della pressione sulle pareti

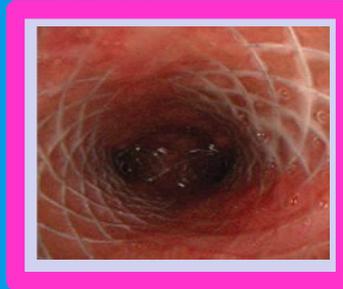


Prolasso fra le maglie dello stent

Impianto di stent



Aggressione (denudazione) del tessuto a contatto con stent



Punti di contatto: maglia-tessuto endoteliale

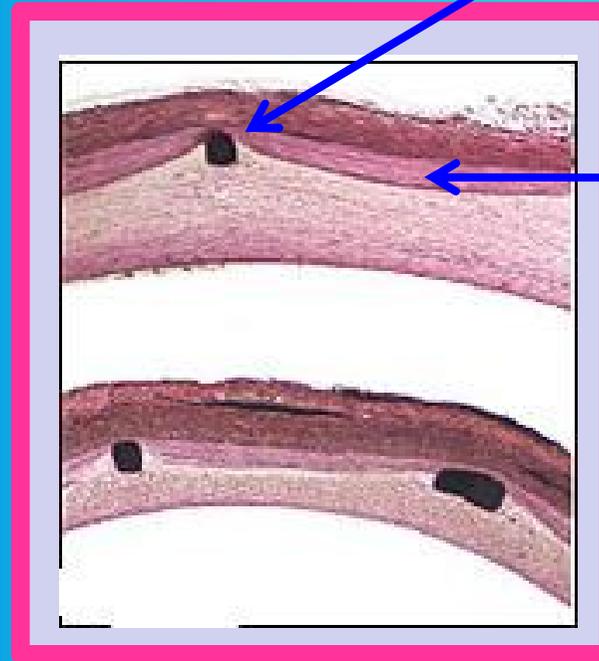
Prolasso vasale



Iperplasia neointimale



Fattore predittivo della restenosi intrastent



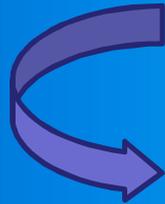
PROLASSO
Protrusione o collasso del tessuto endoteliale tra le maglie dello stent

OBIETTIVO

Capire come varia il
prolasso vasale
dovuto all'impianto
di stent



Geometrie diverse
di stent coronarici



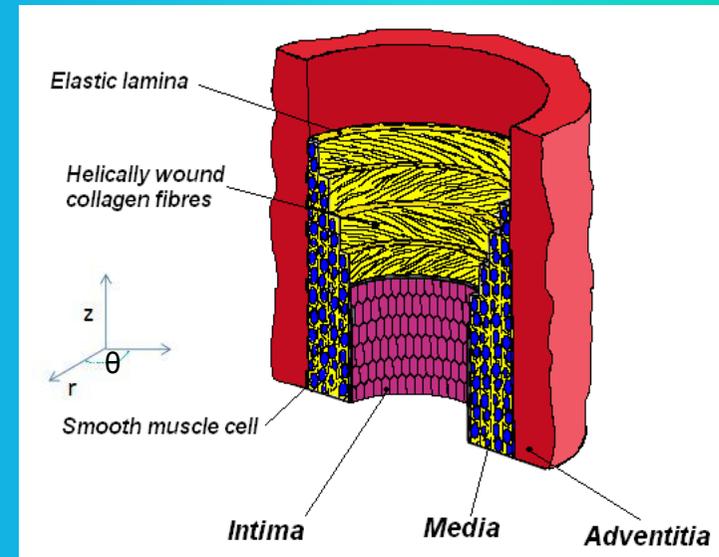
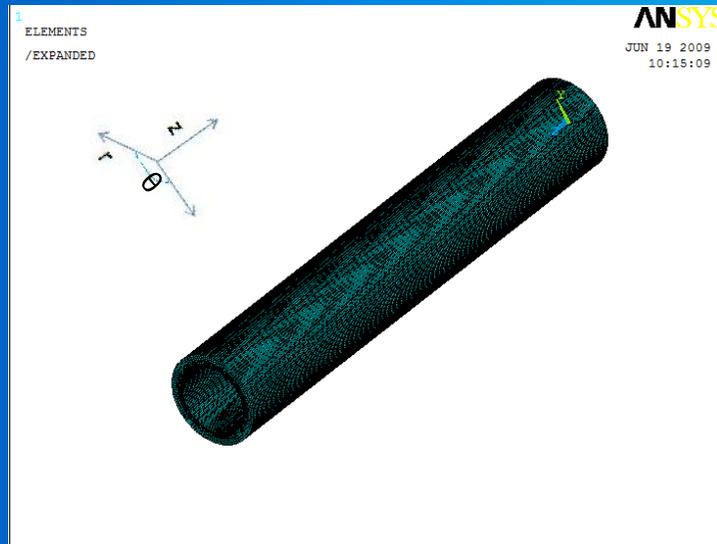
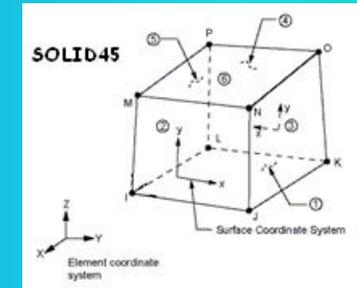
Analisi
parametrica agli
Elementi Finiti
<<ANSYS®>>



Modellazione di un tratto
di coronaria (LDA)

Modello Geometrico

Arteria coronarica modellata come un cilindro di 75168 elementi SOLID45, 86700 nodi tramite il programma di calcolo ANSYS 11.0

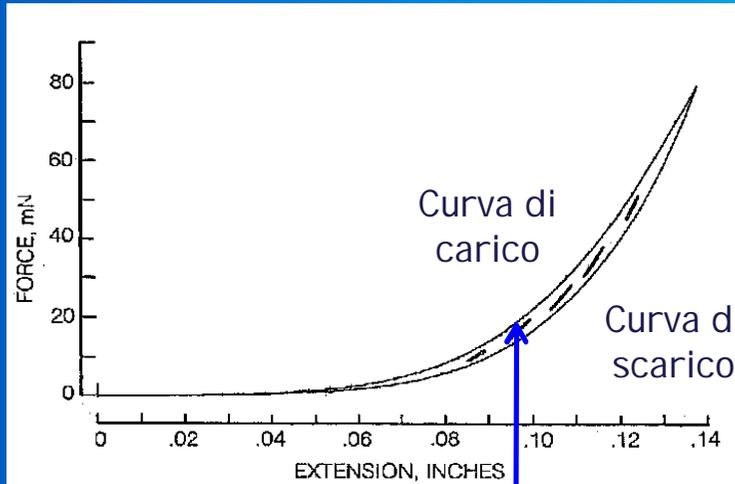


3 Cilindri cavi coassiali
lunghezza 24 mm

tre layer: Intima, Media e Adventizia

	Raggio esterno	Raggio interno	Spessore (E)	Note
Intima	1.6 mm	1.5 mm	0.1 mm	valore medio
Media	1.6 mm	1.75 mm	0.15 mm	valore medio
Adventizia	1.75 mm	2 mm	0.25 mm	valore medio

Materiale



Determinazione sperimentale dei moduli incrementali elastici

Fung Y.C.
Biomechanics: Mechanical Properties of Living Tissues, Springer, 1993

Modellazione semplice e lineare

Formulazione di una legge incrementale

Relazione lineare tra stress e strain incrementali

Kassab, Huang et al.

TEORIA INCREMENTALE

Determinazione moduli elastici incrementali

$$s_{ij} = \frac{\partial(\rho_0 W)}{\partial E_{ij}} \quad (1)$$

s_{ij} stress di Kirchhoff
 E_{ij} strain di Green
 $\rho_0 W$ Strain energy function

$$s_{ij} = s_{ij}^0 + \delta s_{ij} \quad E_{ij} = E_{ij}^0 + \delta E_{ij} \quad (2)$$

Piccole perturbazioni in condizioni fisiologiche

$$\delta s_{ij} = \frac{\partial^2 \rho_0 W}{\partial E_{km} \partial E_{ij}} \delta E_{km} = c_{ijkl} \delta E_{km} \quad (3)$$

equazione lineare del rapporto incrementale stress-strain

$$c_{ijkl} = \frac{\partial^2 \rho_0 W}{\partial E_{km} \partial E_{ij}} \quad (4)$$

Materiale

Teoria incrementale

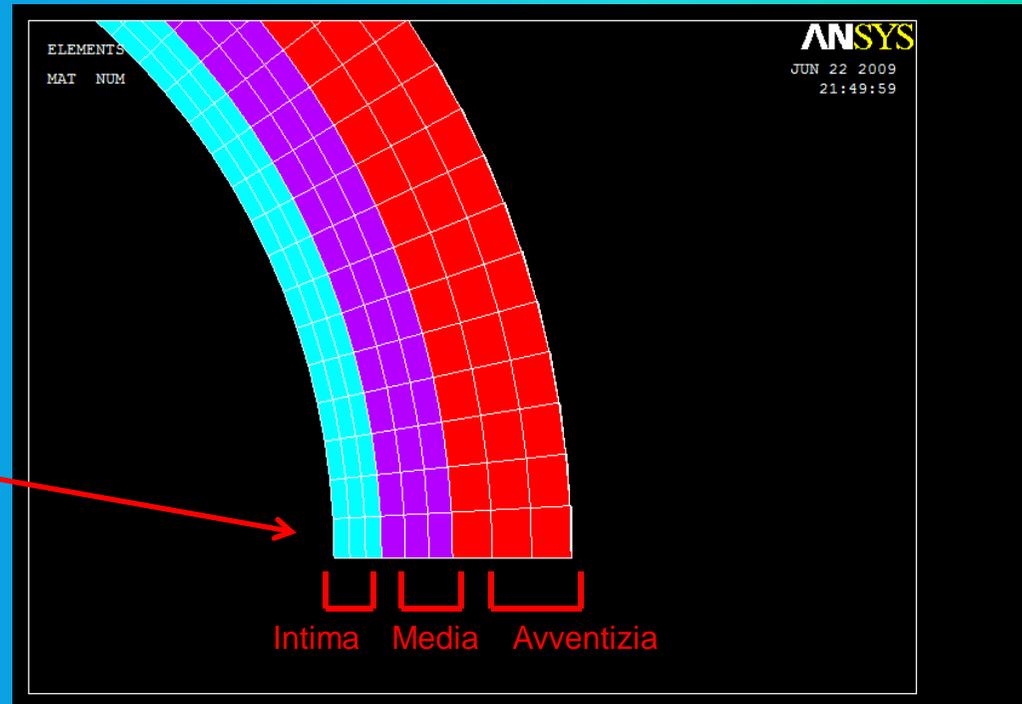
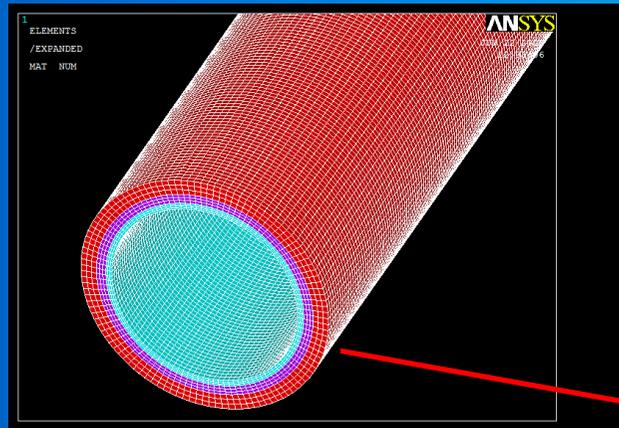
	E_r	E_θ	E_z	$\nu_{r\theta}$	$\nu_{\theta z}$	ν_{rz}	G_r	G_θ	G_z
Intima	0.04 MPa	0.04 MPa	0.29 MPa	0.49	0.49	0.49	0.1	0.0145 MPa	0.0145 MPa
Media	0.299 MPa	0.299 MPa	0.0451 MPa	0.49	0.49	0.49	0.1 MPa	0.015 MPa	0.015 MPa
Avventizia	0.0827 MPa	0.0827 MPa	0.197 MPa	0.49	0.49	0.49	0.15 MPa	0.36 MPa	0.36 MPa

I valori fanno riferimento a tessuti affetti da patologia aterosclerotica e valgono solo per certi range di tensione media

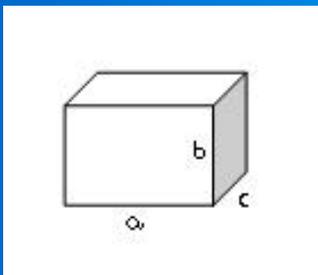
Vantaggio all'utilizzo dei moduli incrementali:
trattare un tessuto come un materiale elastico lineare

- Materiale lineare elastico incomprimibile (moduli incrementali)
 - Parete vasale eterogenea (Intima, Media e Avventizia)
 - Proprietà di trasversa isotropia diverse per ogni layer

MESH



1. Numero minimo di divisioni dello spessore di ogni layer = 3, per avere informazioni su ogni layer
2. Rapporto di proporzionalità, affinché siano attendibili le informazioni su ogni elemento



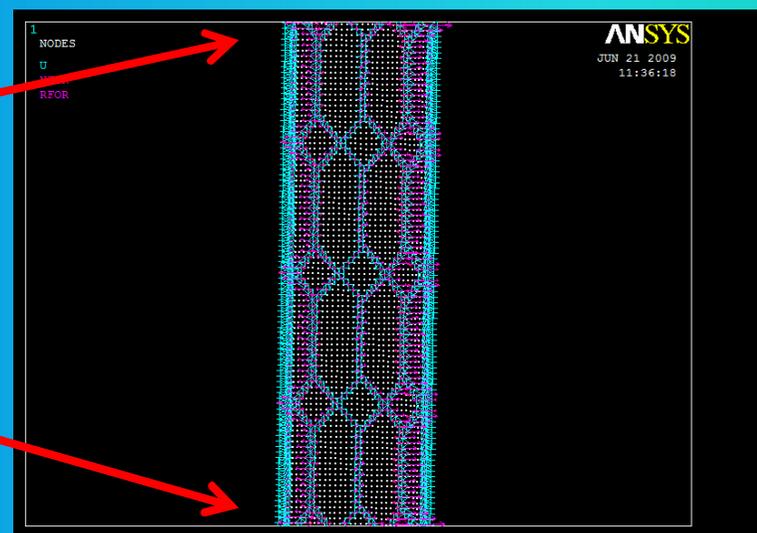
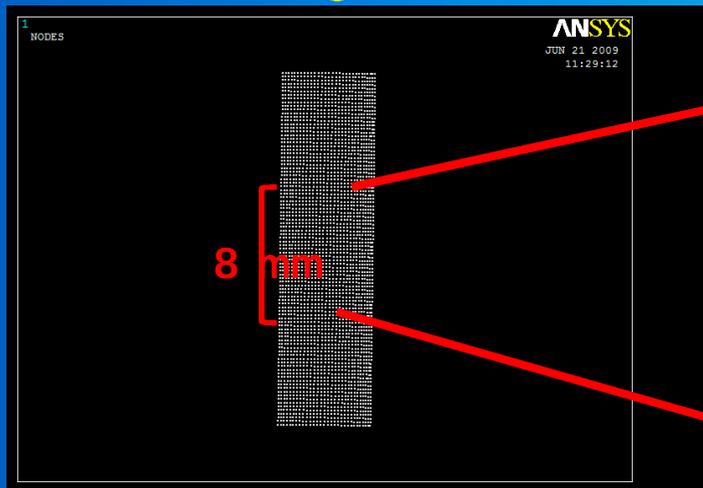
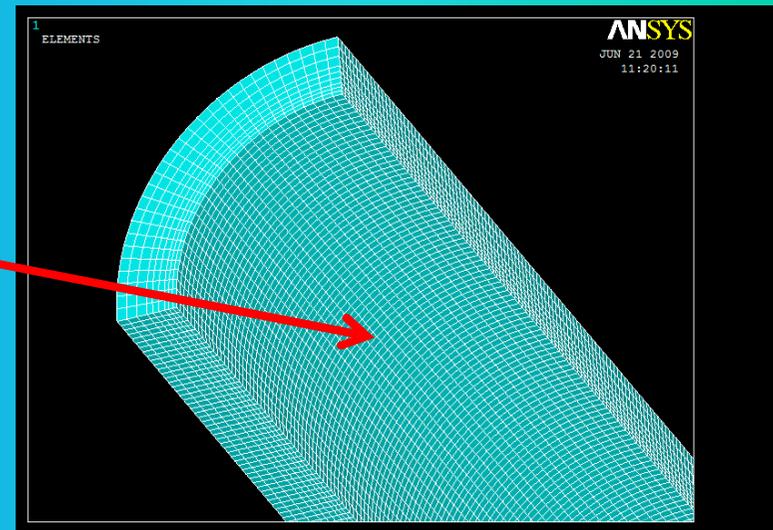
Elemento Solid45

$$\frac{a}{c} = \frac{b}{c} = \frac{b}{a} \leq 2.5$$

Caratteristiche possedute da ogni singolo elemento:

Condizioni di carico

Applicazione di uno spostamento radiale di prova sui nodi della parete interna del vaso (8 mm) coincidenti con i punti di applicazione dello stent in riferimento alla sua posizione e geometria



ANALISI A GRANDI DEFORMAZIONI

Analisi effettuate

ANALISI 1

Geometria di ogni specifico stent



Diverso valore del passo della maglia

- 1 mm
- 2 mm

Passo dello stent

ANALISI 2

Geometria di ogni specifico stent



Diverso spostamento radiale della maglia sulla parete vasale

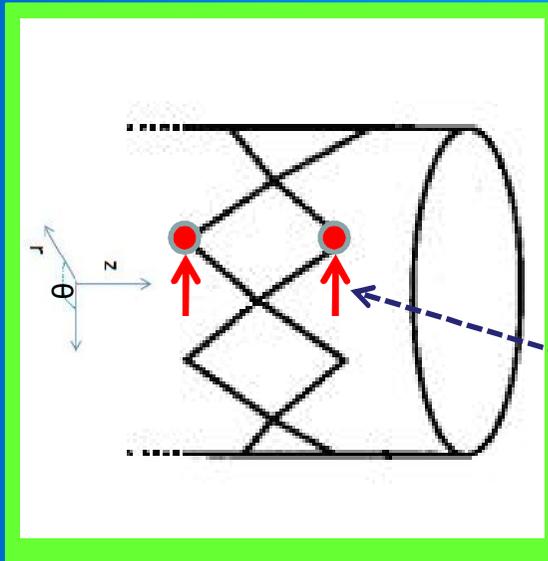
ANALISI 3



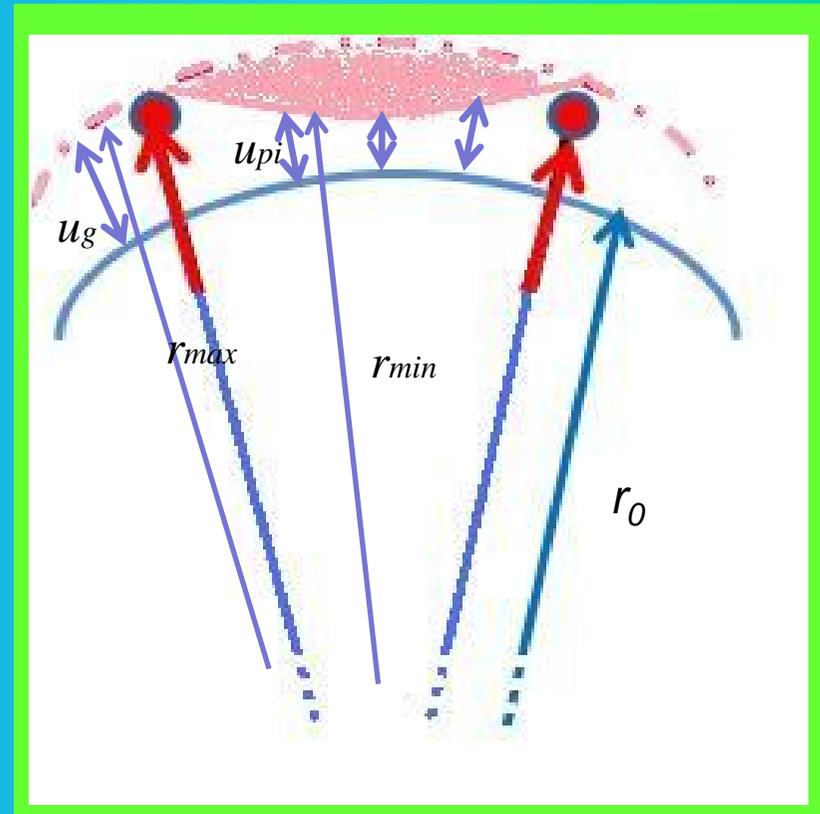
Confronto fra tipologie di geometria diversa di stent presenti in commercio

Valutazione qualitativa di prolasso attraverso le maglie

Prolasso fra le maglie dello stent



Spostamento radiale nei punti di contatto della maglia con la parete



$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100$$

$$r_{max} = r_0 + u_g$$

$$r_{mini} = r_0 + u_{pi}$$

r_0 raggio lume vasale = 1.5 mm

u_g = spostamento applicato nei punti di contatto della maglia con l'intima vasale

u_{pi} = distanza fra i punti i-esimi di prollasso e il lume vasale

Risultati

•0,01 mm

Diverse tipologie di stent

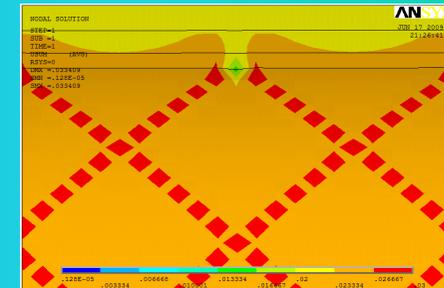
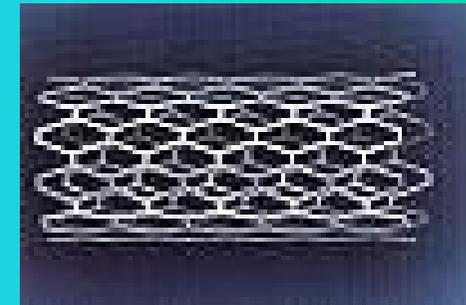
Palmaz-Schwartz BEIS con passo 1 mm

$$Pi = [(rmax - rmini)/ ug] \times 100 \quad \text{Prolasso}$$

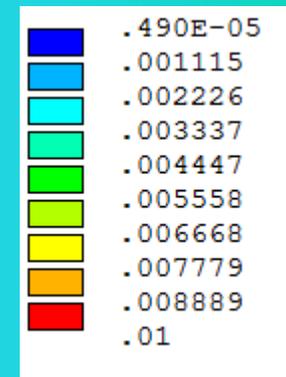
$$rmin = r_0 + 0.0088 \text{ mm}$$

$$\underline{Pmax = 11.3 \%}$$

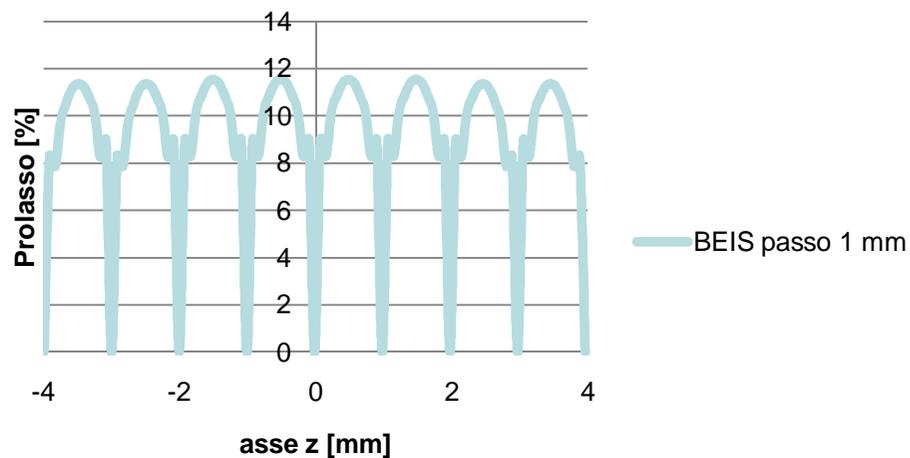
$$rmax = r_0 + 0.01 \text{ mm}$$



Spostamento radiale [mm]



BEIS passo 1 mm



Risultati

Diverse tipologie di stent

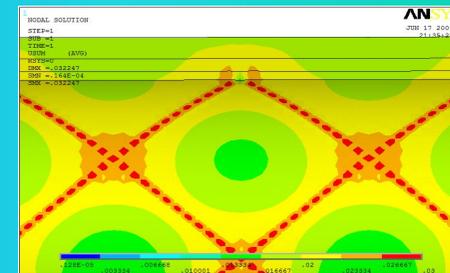
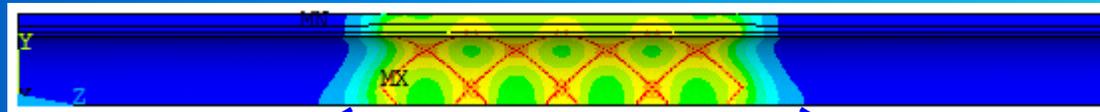
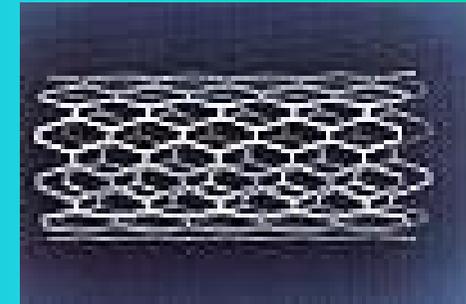
Palmaz-Schwartz BEIS con passo 2 mm

$$Pi = [(rmax - rmini) / ug] \times 100 \quad \text{Prolasso}$$

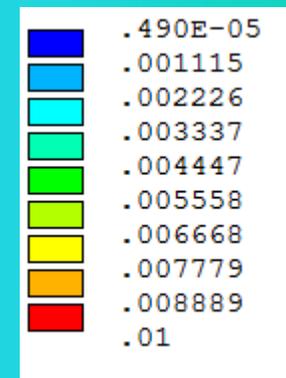
$$rmin = r_0 + 0.0072 \text{ mm}$$

$$Pmax = 28 \%$$

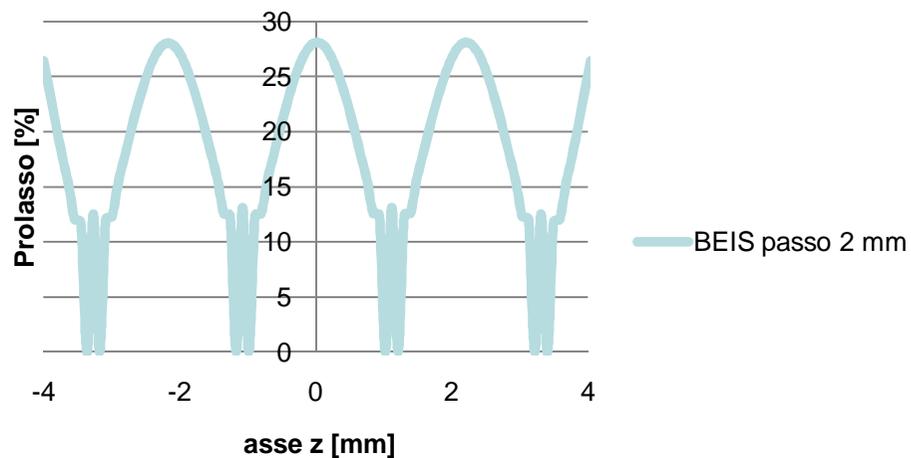
$$rmax = r_0 + 0.01 \text{ mm}$$



Spostamento radiale [mm]



BEIS passo 2 mm



Risultati

Diverse tipologie di stent

•0,01 mm

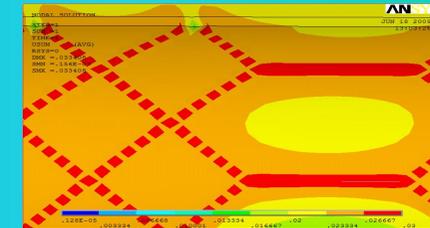
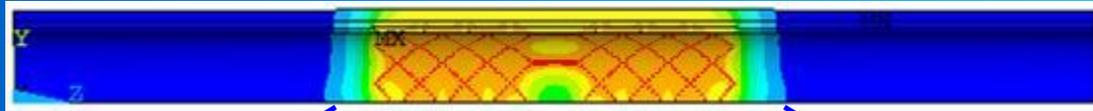
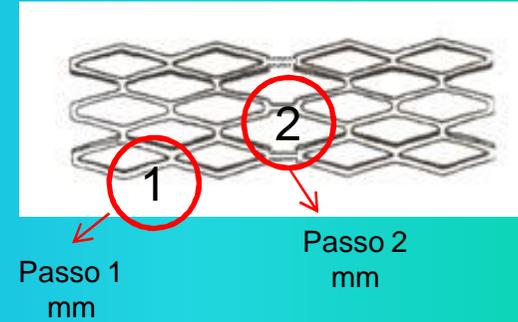
Palmaz-Schwatz ABEIS

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100 \quad \text{Prolasso}$$

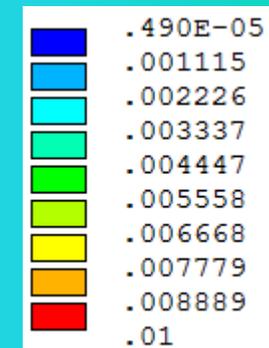
1 $r_{min} = r_0 + 0.0087 \text{ mm}$ \longrightarrow P = 11.3%

2 $r_{min} = r_0 + 0.0084 \text{ mm}$ \longrightarrow P max= 16 %

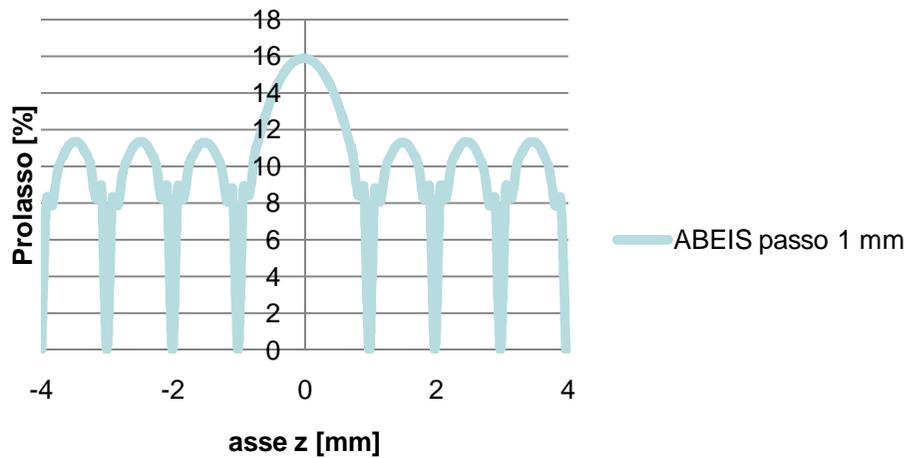
$$r_{max} = r_0 + 0.01 \text{ mm}$$



Spostamento radiale [mm]



ABEIS passo 1 mm



Risultati

•0,01 mm

Diverse tipologie di stent

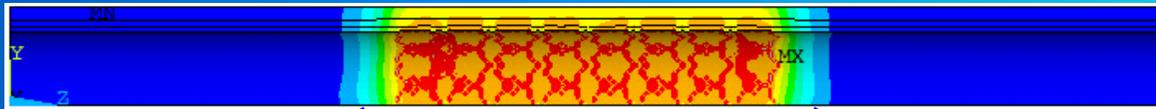
Palmaz-Schwartz Crown con passo 1 mm

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100 \quad \text{Prolasso}$$

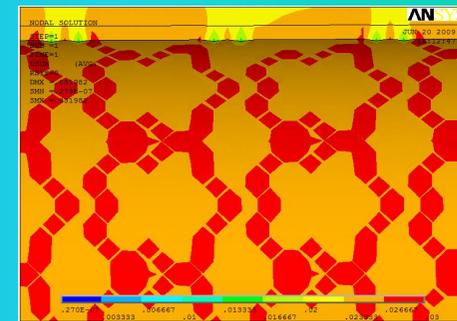
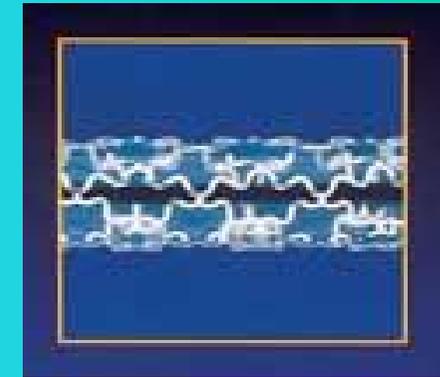
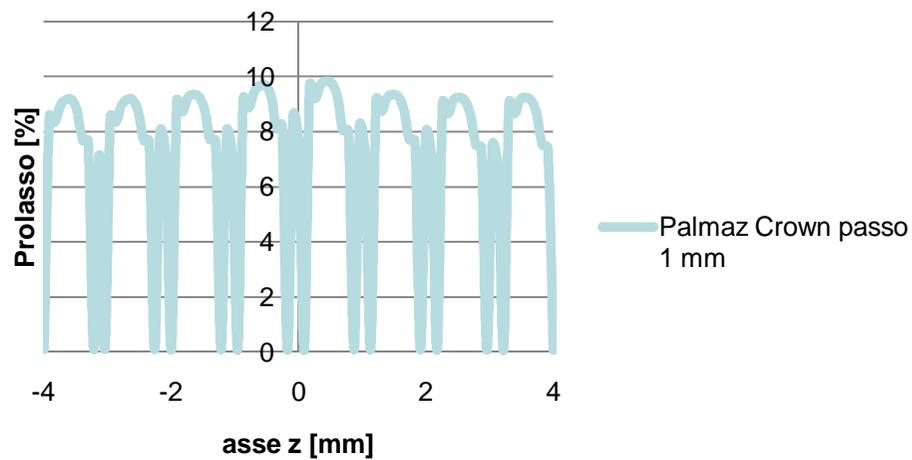
$$r_{min} = r_0 + 0.0090 \text{ mm}$$

$$r_{max} = r_0 + 0.01 \text{ mm}$$

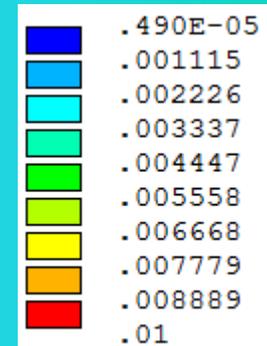
P max= 10 %



Palmaz Crown passo 1 mm



Spostamento radiale [mm]



Risultati

•0,01 mm

Diverse tipologie di stent

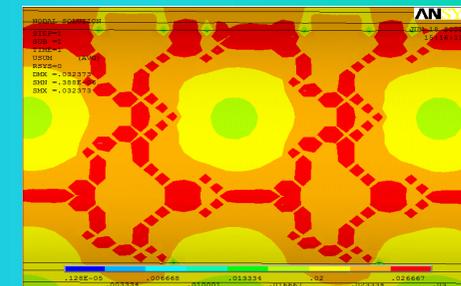
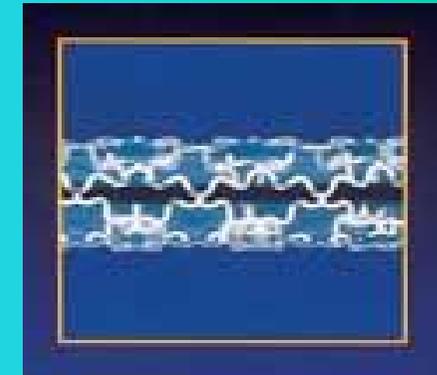
Palmaz-Schwartz Crown con passo 2 mm

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100 \quad \text{Prolasso}$$

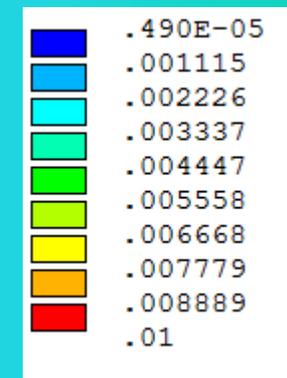
$$r_{min} = r_0 + 0.0078 \text{ mm}$$

$$r_{max} = r_0 + 0.01 \text{ mm}$$

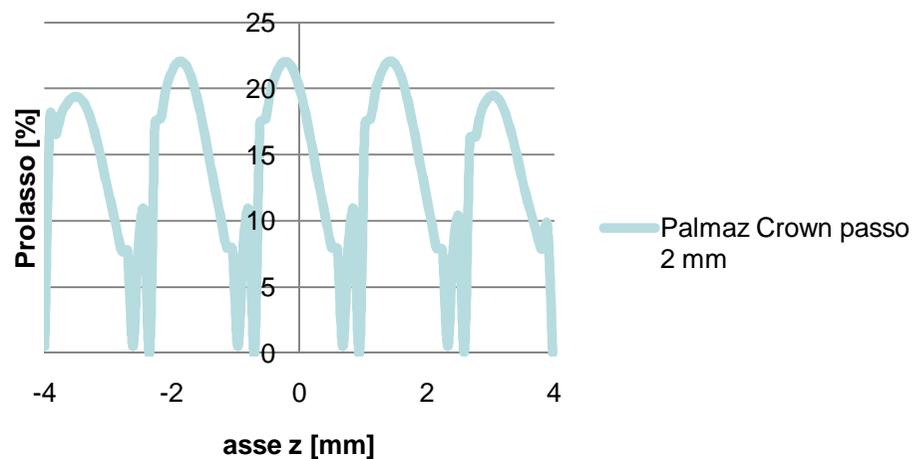
→ P max= 22 %



Spostamento radiale [mm]



Palmaz Crown passo 2 mm



Risultati

Diverse tipologie di stent

•0,01 mm

Coronary Cardiocoil stent con passo 1 mm

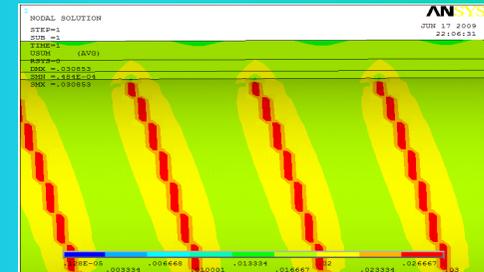
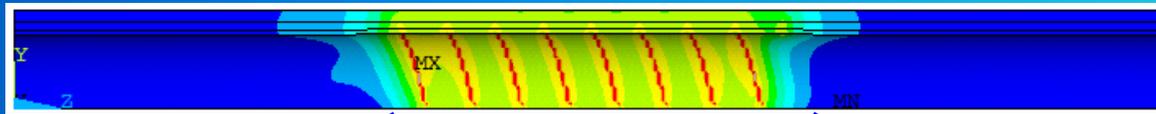
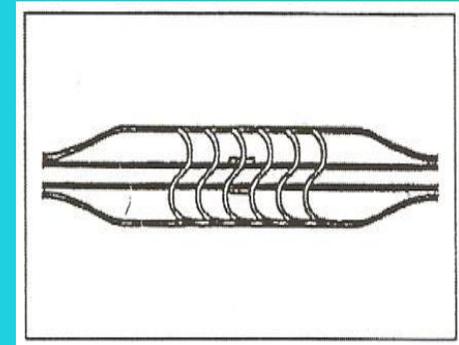
$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100$$

Prolasso

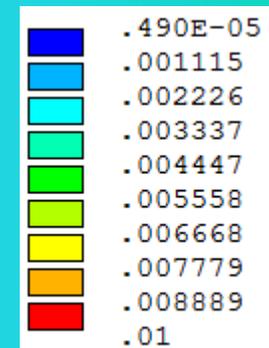
$$r_{min} = r_0 + 0.0078 \text{ mm}$$

$$r_{max} = r_0 + 0.01 \text{ mm}$$

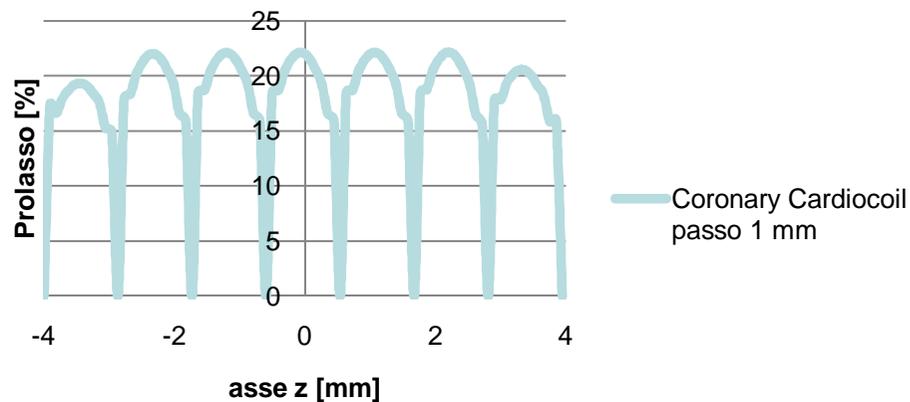
P max= 23 %



Spostamento radiale [mm]



Coronary Cardiocoil passo 1 mm



Risultati

Diverse tipologie di stent

•0,01 mm

Coronary Cardiocoil stent con passo 2 mm

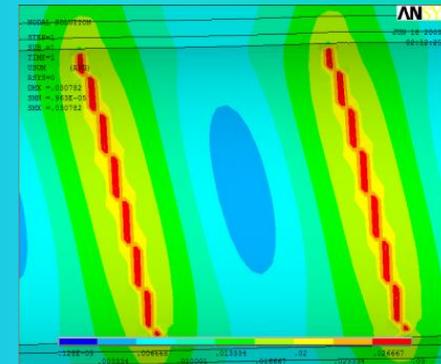
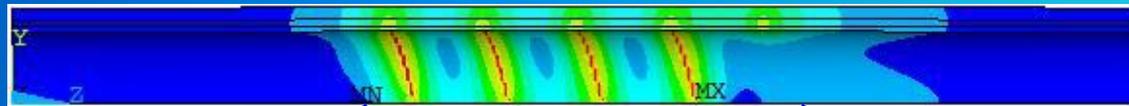
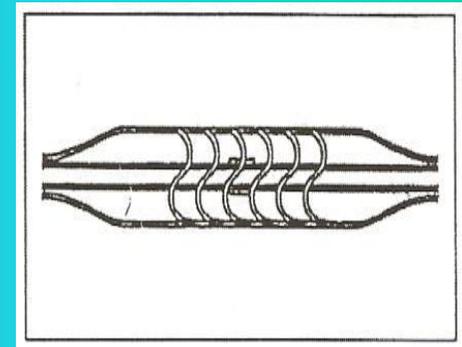
$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100$$

$$r_{min} = r_0 + 0.005 \text{ mm}$$

$$r_{max} = r_0 + 0.01 \text{ mm}$$

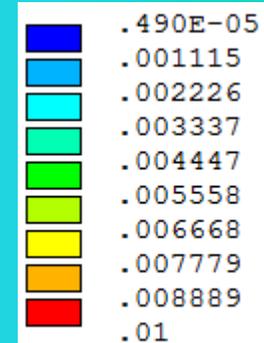
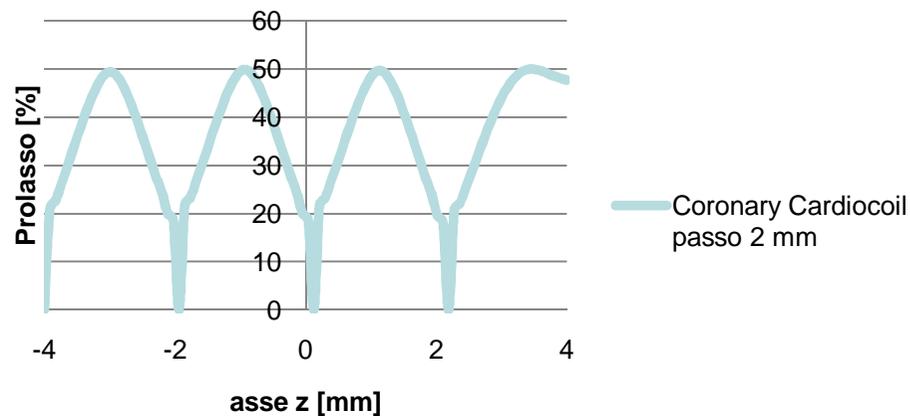
Prolasso

P max = 50 %



Spostamento radiale [mm]

Coronary Cardiocoil passo 2 mm



Risultati

Diverse tipologie di stent

•0,01 mm

Joflex stent con passo 1 mm

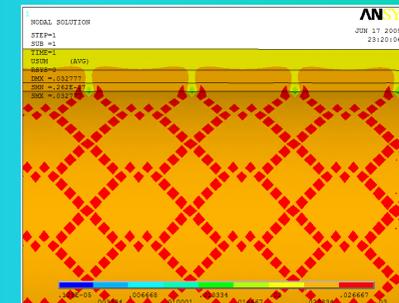
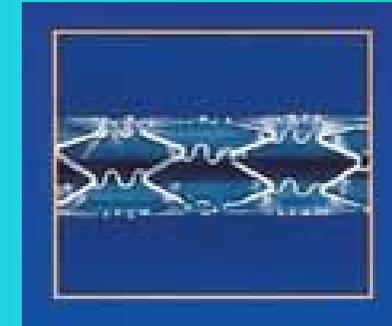
$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100$$

$$r_{min} = r_0 + 0.0090 \text{ mm}$$

$$r_{max} = r_0 + 0.01 \text{ mm}$$

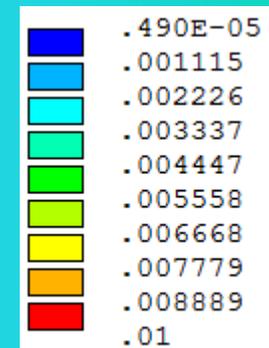
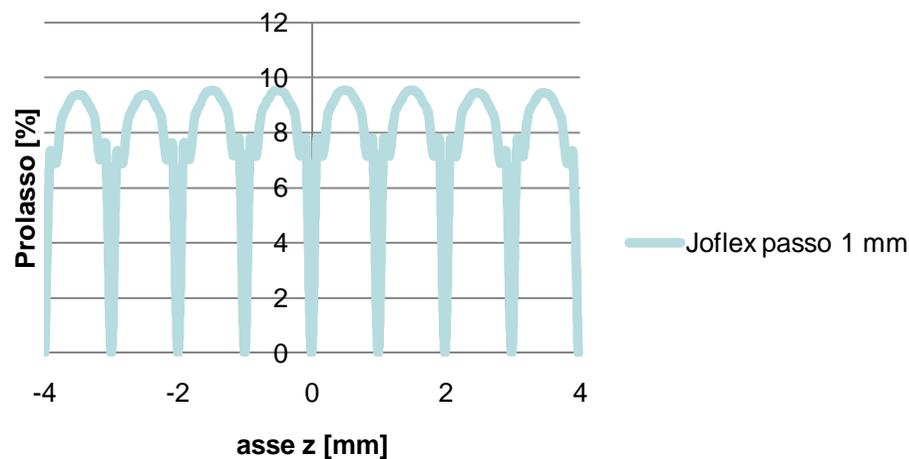
Prolasso

→ Pmax = 10 %



Spostamento radiale [mm]

Joflex passo 1 mm



Risultati

Diverse tipologie di stent

•0,01 mm

Joflex stent con passo 2 mm

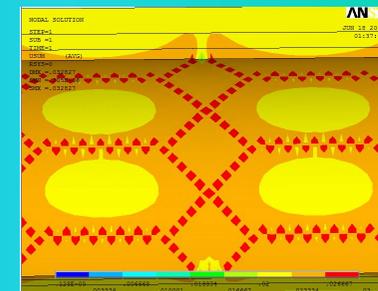
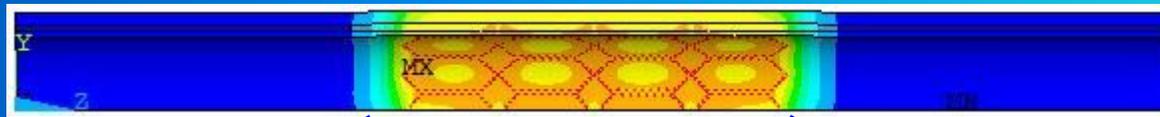
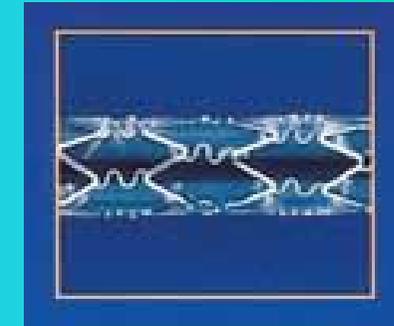
$$Pi = [(rmax - rmini) / ug] \times 100$$

Prolasso

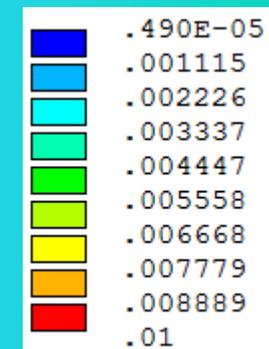
$$rmin = r_0 + 0.0084 \text{ mm}$$

$$rmax = r_0 + 0.01 \text{ mm}$$

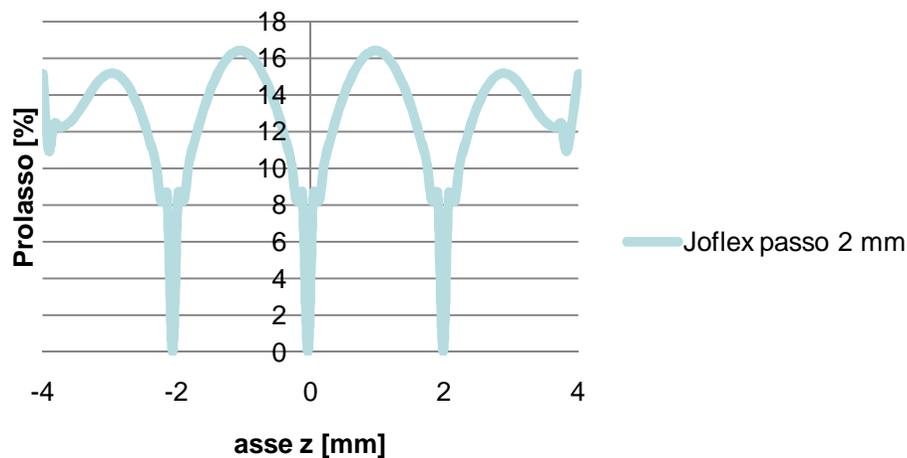
→ P max= 16.4 %



Spostamento radiale [mm]



Joflex passo 2 mm



Risultati

Diverse tipologie di stent

•0,01 mm

NIR stent con passo 1 mm

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100$$

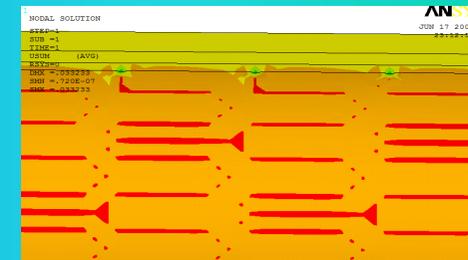
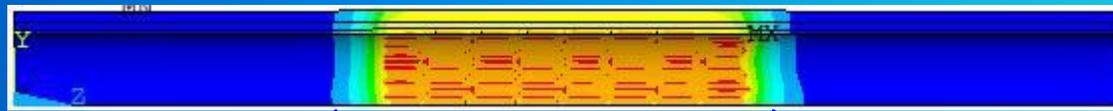
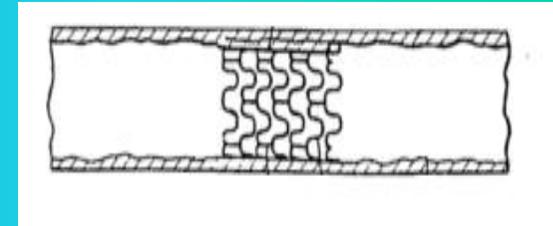
Prolasso

$$r_{min} = r_0 + 0.0093 \text{ mm}$$

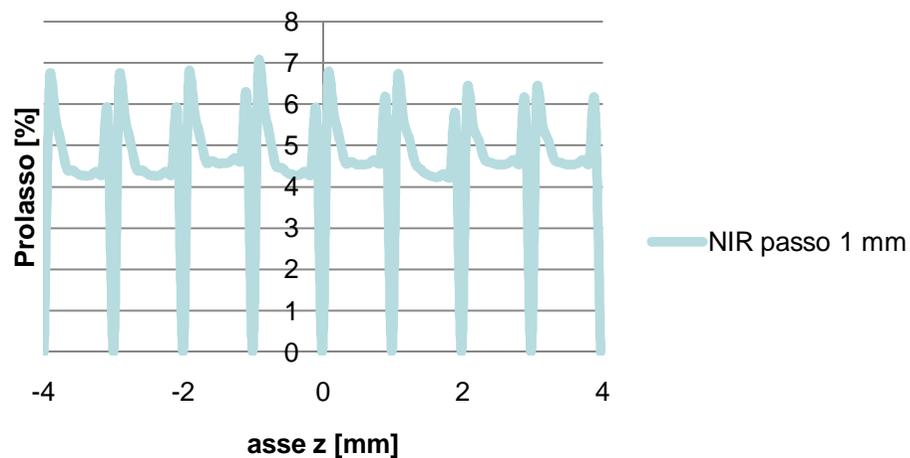
$$P_{max} = 7 \%$$

$$r_{max} = r_0 + 0.01 \text{ mm}$$

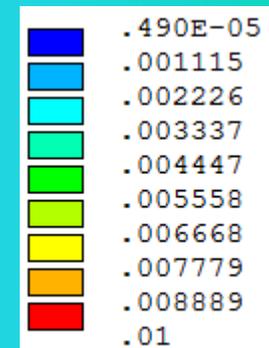
$$P = 4.5 \%$$



NIR passo 1 mm



Spostamento radiale [mm]



Risultati

Diverse tipologie di stent

•0,01 mm

NIR stent con passo 2 mm

$$Pi = [(rmax - rmini) / ug] \times 100$$

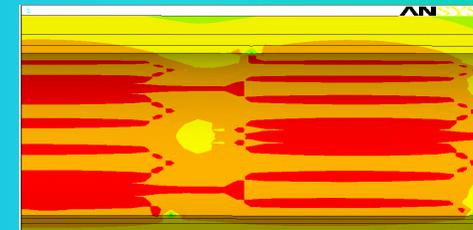
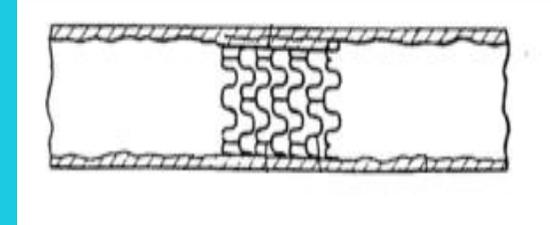
$$rmin = r_0 + 0.0085 \text{ mm}$$

$$rmax = r_0 + 0.01 \text{ mm}$$

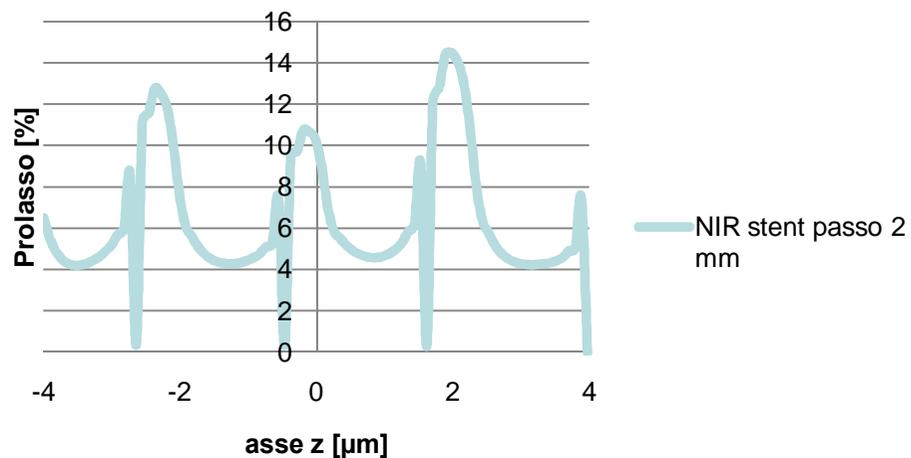
Prolasso

$$Pmax = 15 \%$$

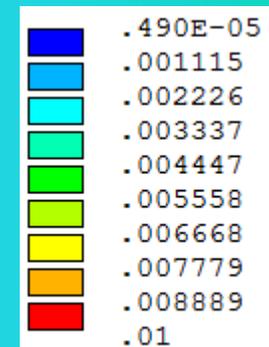
$$P = 5 \%$$



NIR stent passo 2 mm



Spostamento radiale [mm]



•0,04 mm

Risultati

Diverse tipologie di stent

Palmaz-Schwartz BEIS con passo 1 mm

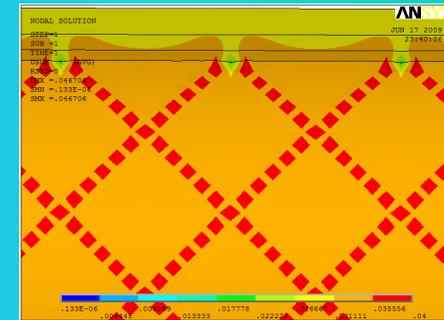
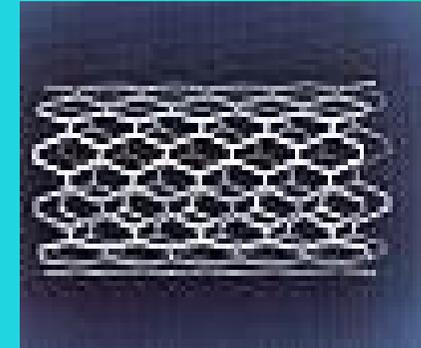
$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100$$

Prolasso

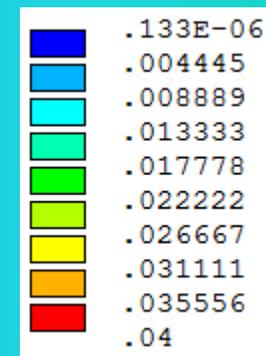
$$r_{mini} = r_0 + 0.032 \text{ mm}$$

$$r_{max} = r_0 + 0.04 \text{ mm}$$

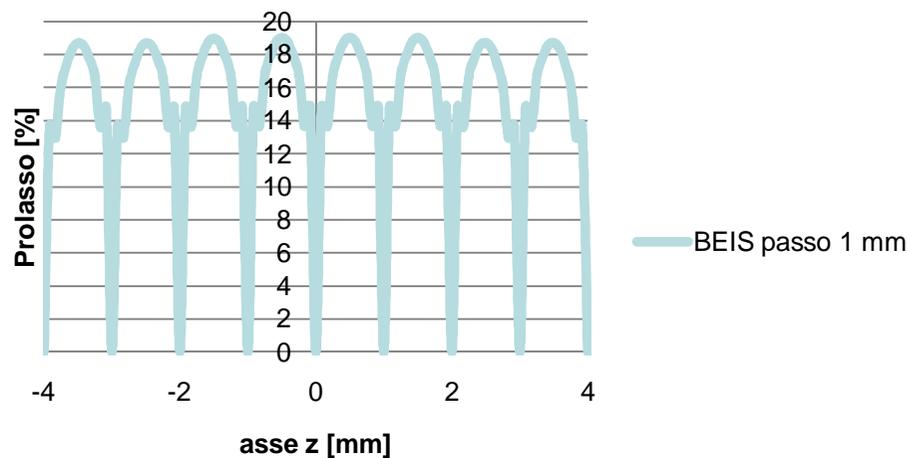
P = 19 %



Spostamento radiale [mm]



BEIS passo 1 mm



•0,04 mm

Risultati

Diverse tipologie di stent

Palmaz-Schwartz ABEIS

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100 \quad \text{Prolasso}$$

1 $r_{min} = r_0 + 0.032 \text{ mm}$

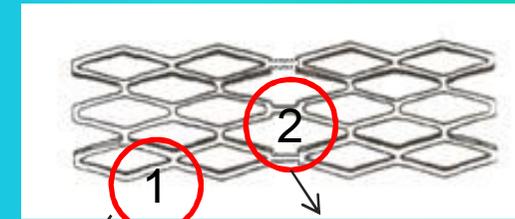


$P = 19 \%$

2 $r_{min} = r_0 + 0.029 \text{ mm}$
 $r_{max} = r_0 + 0.04 \text{ mm}$

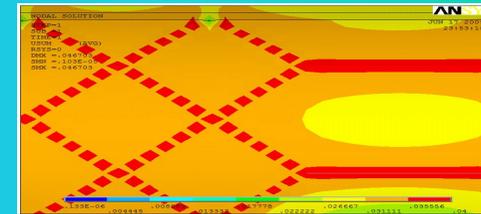
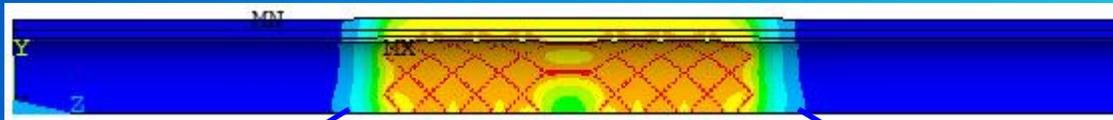


$P = 26.3 \%$



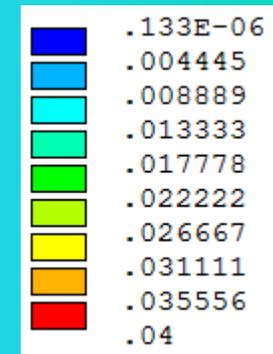
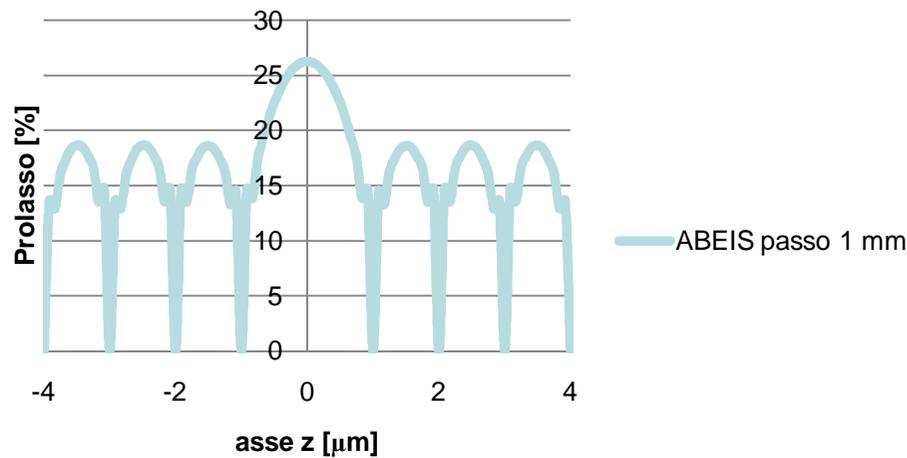
Passo 1 mm

Passo 2 mm



Spostamento radiale [mm]

ABEIS passo 1 mm



•0,04 mm

Risultati

Diverse tipologie di stent

Palmaz-Schwartz Crown con passo 1 mm

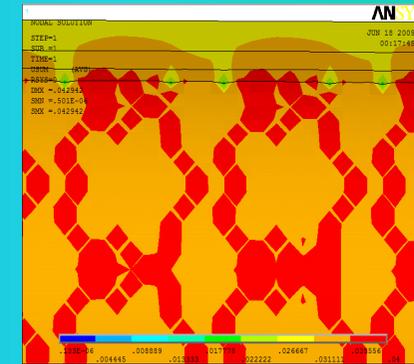
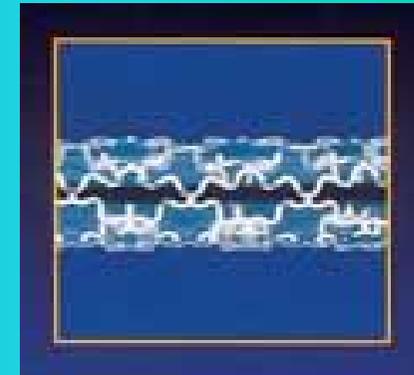
$$Pi = [(rmax - rmini) / ug] \times 100$$

Prolasso

$$rmin = r_0 + 0.034 \text{ mm}$$

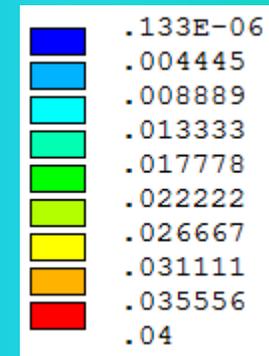
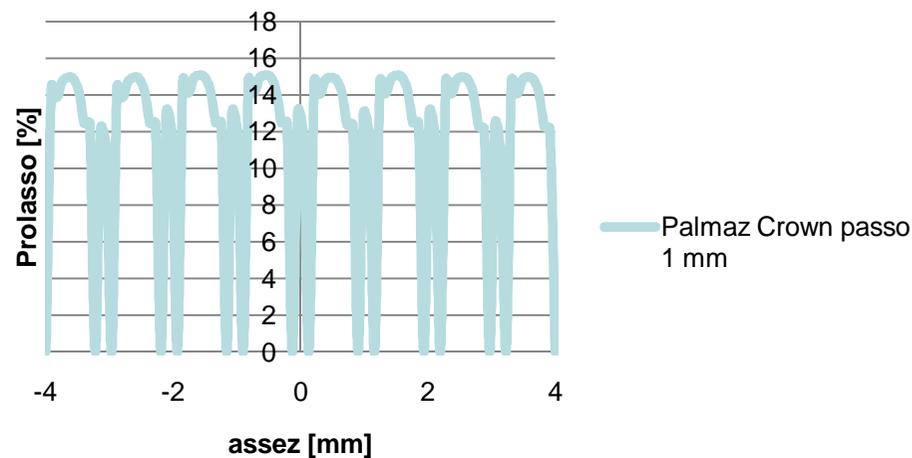
$$rmax = r_0 + 0.04 \text{ mm}$$

→ **P = 16 %**



Spostamento radiale [mm]

Palmaz Crown passo 1 mm



•0,04 mm

Risultati

Diverse tipologie di stent

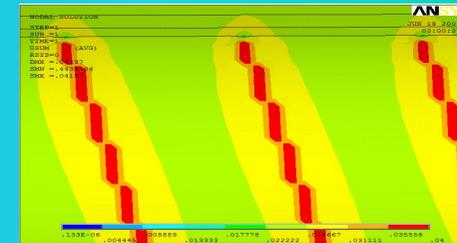
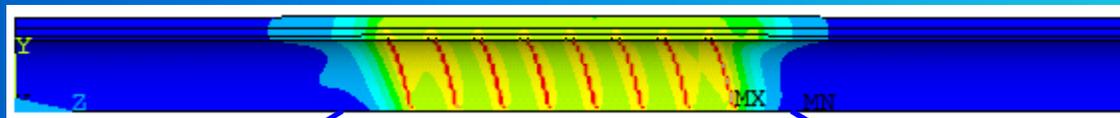
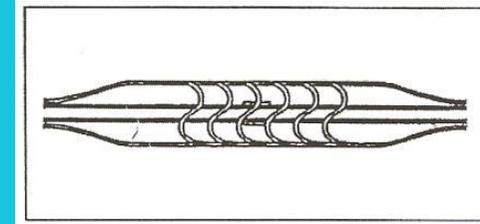
Coronary Cardiocoil stent con passo 1 mm

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100 \quad \text{Prolasso}$$

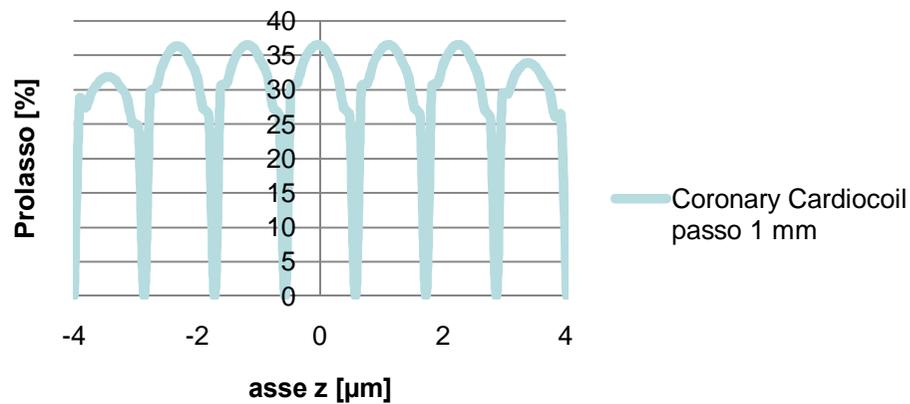
$$r_{min} = r_0 + 0.0255 \text{ mm}$$

$$r_{max} = r_0 + 0.04 \text{ mm}$$

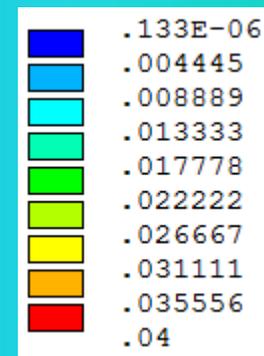
—————→ **P = 36.5 %**



Coronary Cardiocoil passo 1 mm



Spostamento radiale [mm]



•0,04 mm

Risultati

Diverse tipologie di stent

Joflex stent con passo 1 mm

$$P_i = [(r_{max} - r_{mini}) / u_g] \times 100 \quad \text{Prolasso}$$

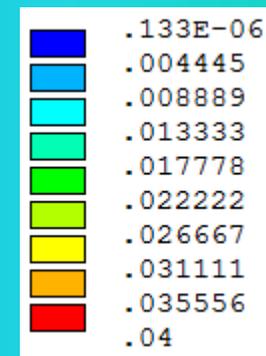
$$r_{min} = r_0 + 0.034 \text{ mm}$$

$$r_{max} = r_0 + 0.04 \text{ mm}$$

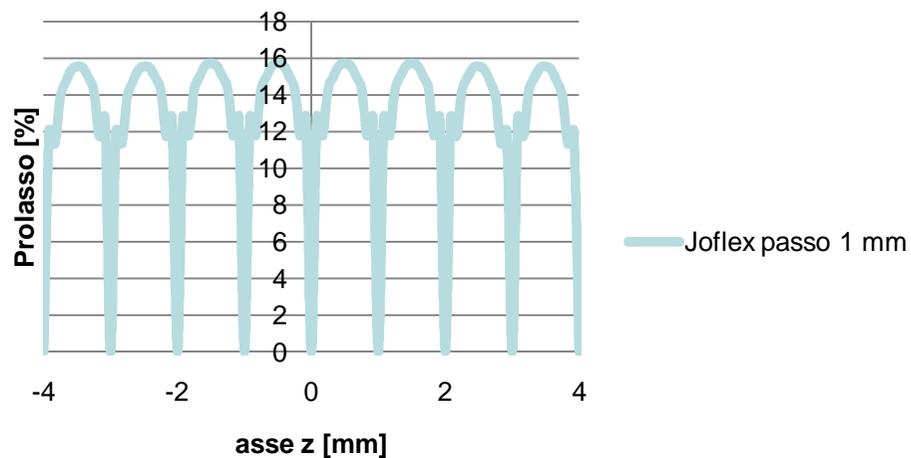
P = 16 %



Spostamento radiale [mm]



Joflex passo 1 mm



•0,04 mm

Risultati

Diverse tipologie di stent

NIR stent con passo 1 mm

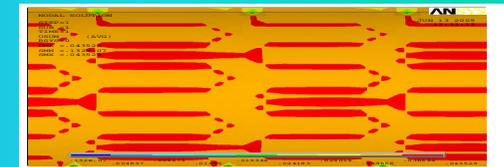
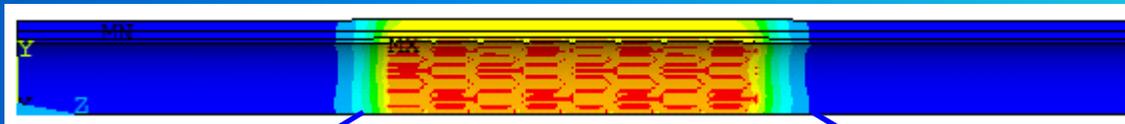
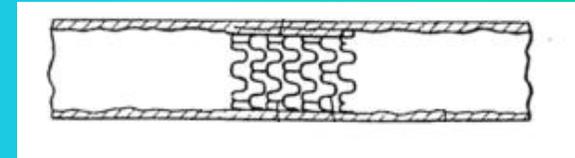
$$Pi = [(rmax - rmini) / ug] \times 100$$

Prolasso

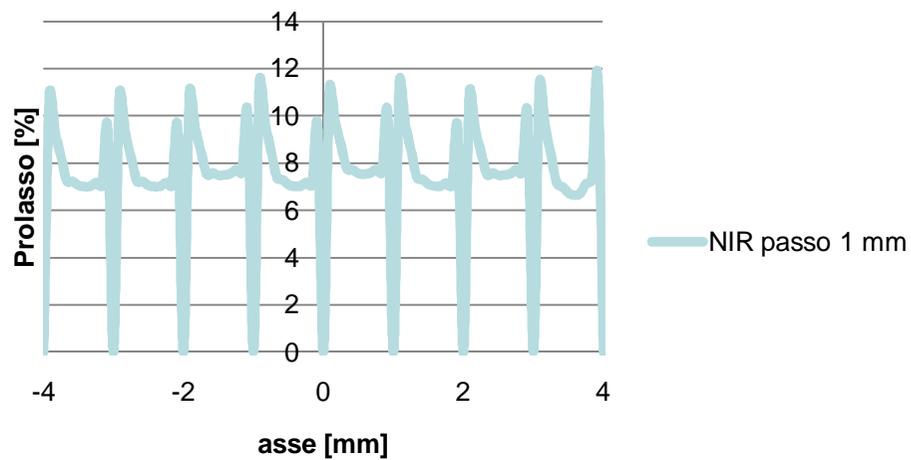
$$rmin = r_0 + 0.037 \text{ mm}$$

$$rmax = r_0 + 0.04 \text{ mm}$$

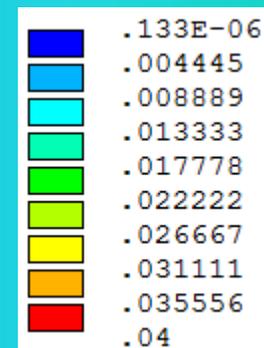
P = 12 %



NIR passo 1 mm



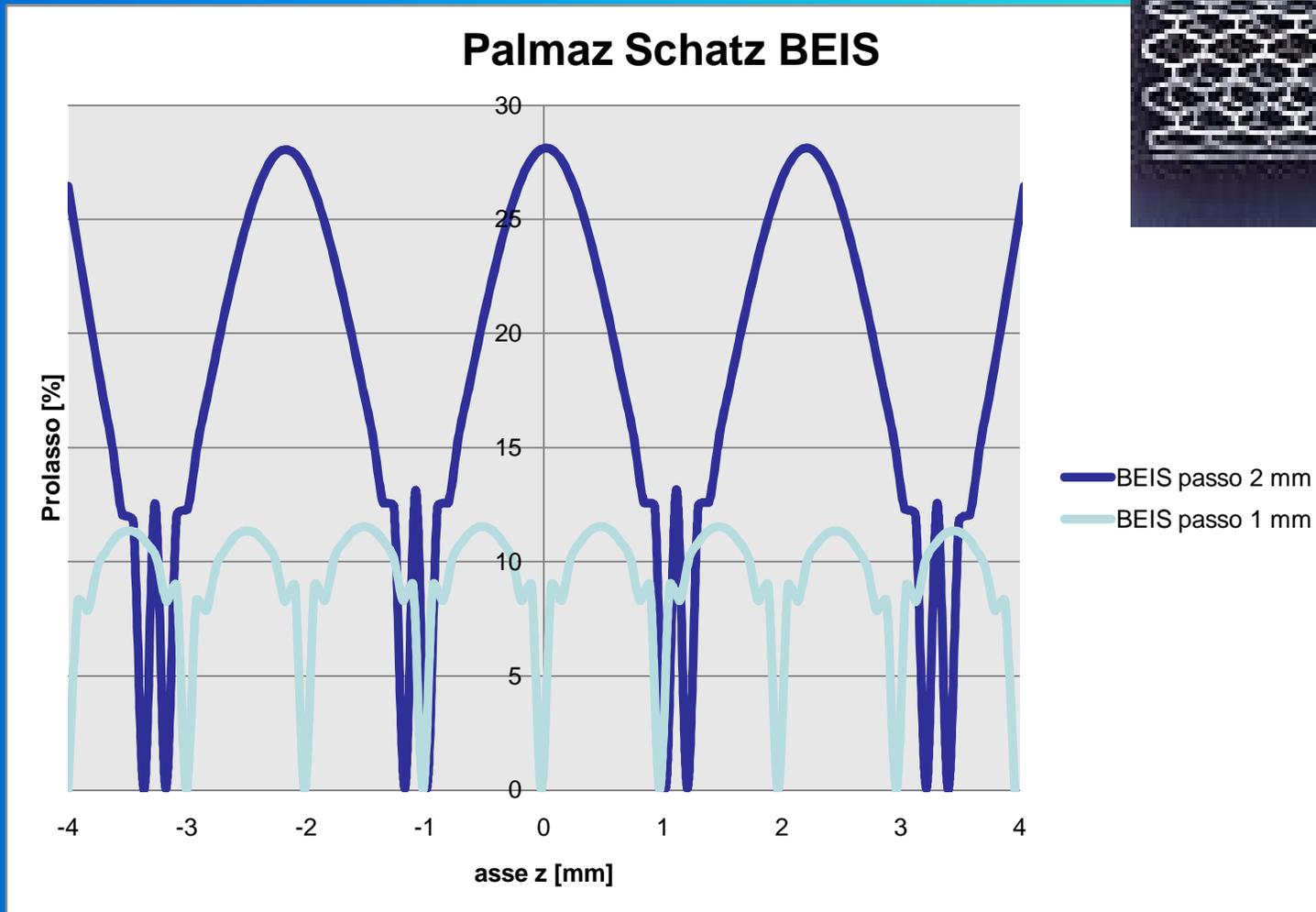
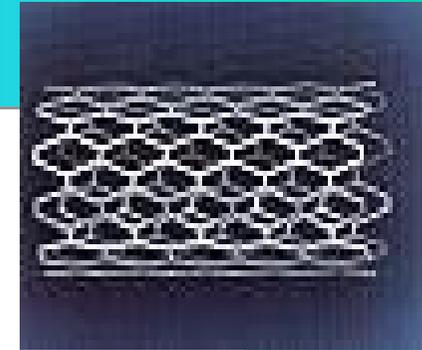
Spostamento radiale [mm]



Conclusioni

Analisi 1

Al variare del passo della maglia

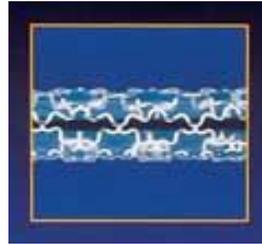
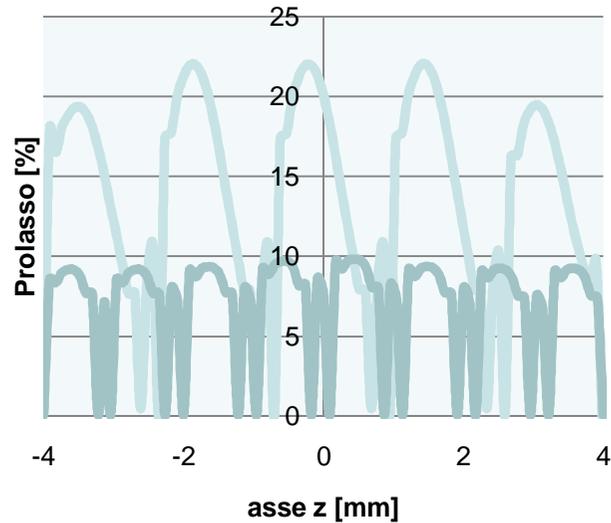


Conclusioni

Analisi 1

Al variare del passo della maglia

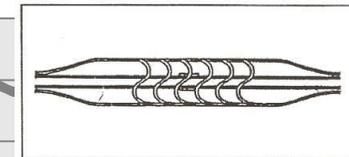
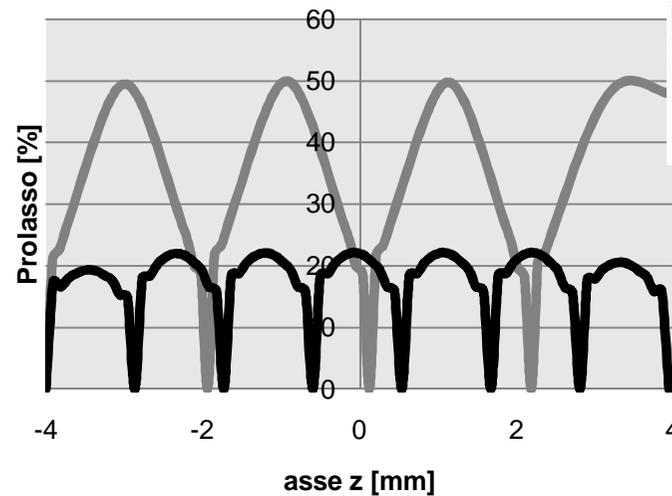
Palmaz Crown



- Palmaz Crown passo 2 mm
- Palmaz Crown passo 1 mm

All'aumentare del passo della maglia la percentuale di prolasso aumenta più del doppio

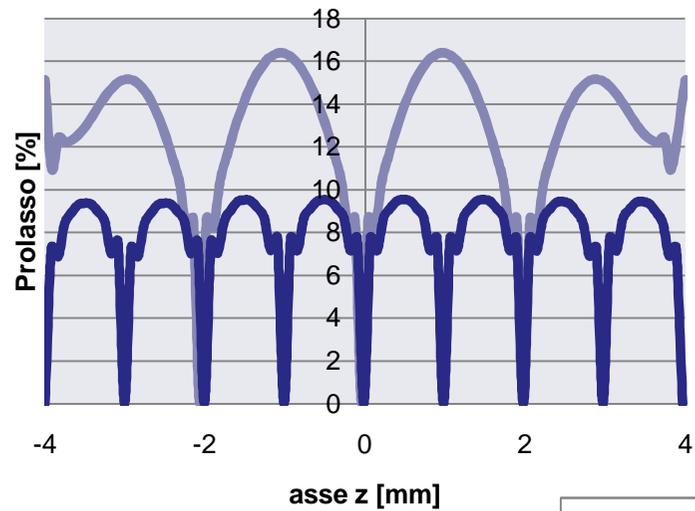
Coronary Cardiocoil stent



- Coronary Cardiocoil passo 2 mm
- Coronary Cardiocoil passo 1 mm

Conclusioni

Joflex stent



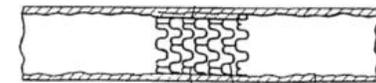
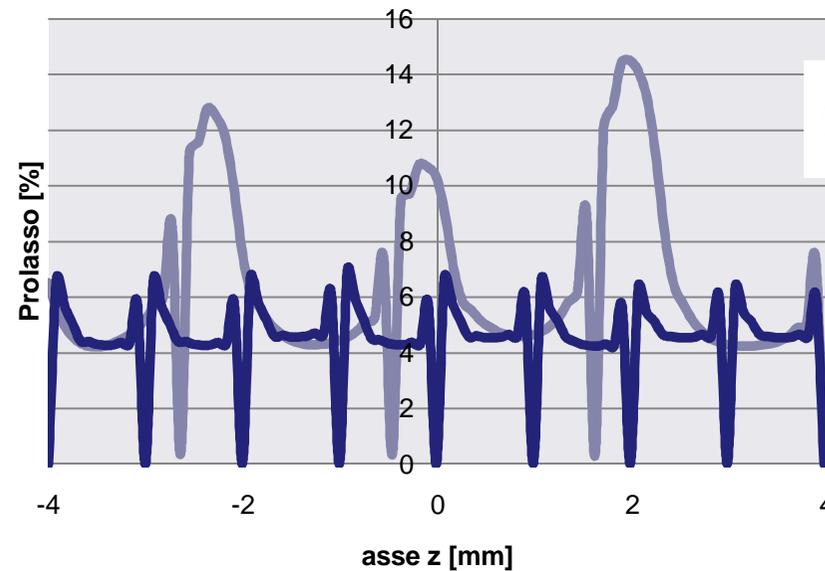
— Joflex passo 2 mm
— Joflex passo 1 mm

Analisi 1

Al variare del passo della maglia

All'aumentare del passo della maglia la percentuale di prolasso aumenta più del doppio

NIR stent

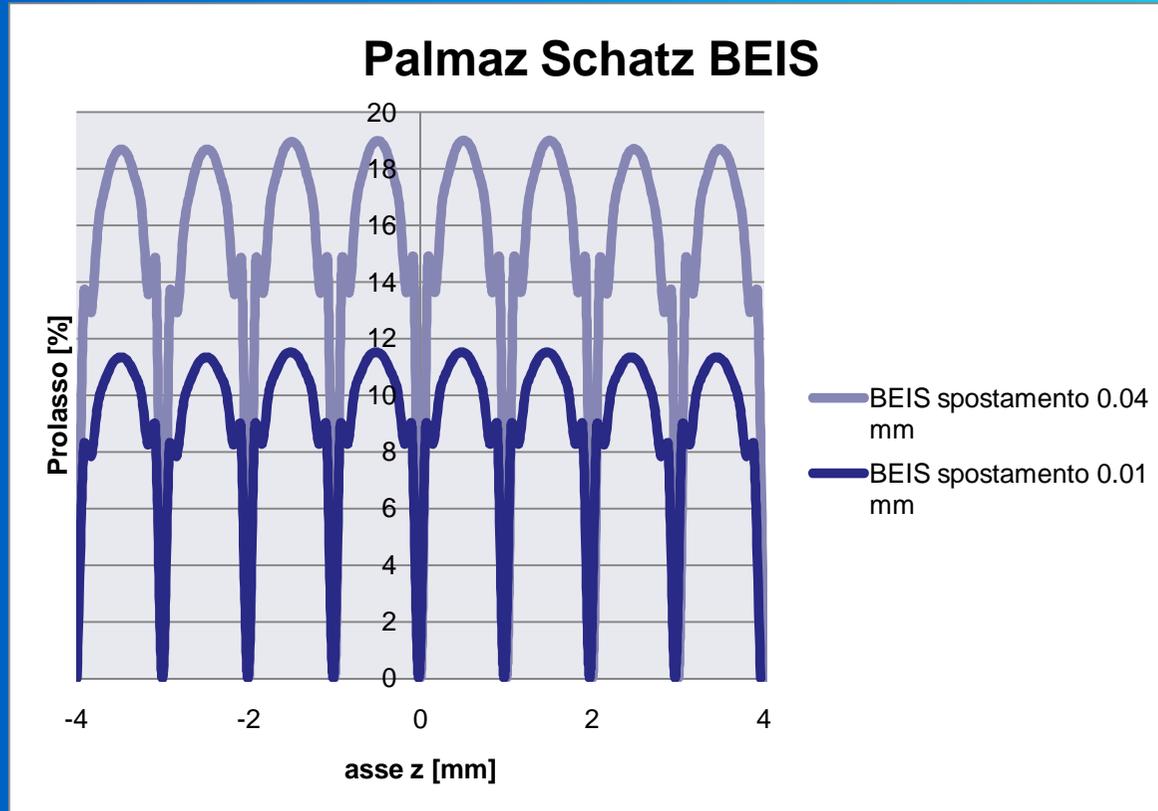


— NIR stent passo 2 mm
— NIR stent passo 1 mm

Conclusioni

Analisi 2

Al variare dello spostamento della maglia



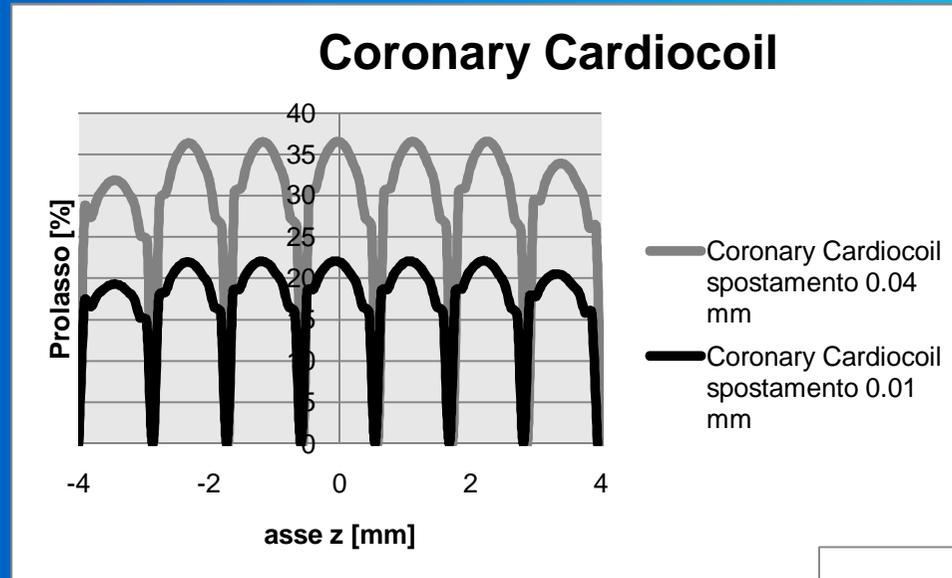
Passo della maglia costante

Mantenendo costante il passo della maglia, facciamo variare lo spostamento radiale dello stent sulla parete vasale

Analisi 2

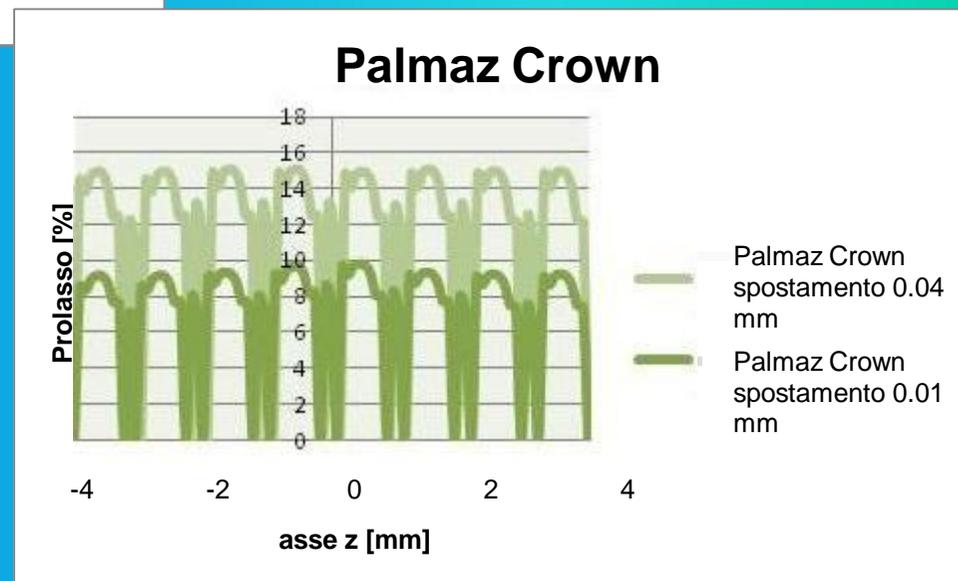
Conclusioni

Al variare dello spostamento della maglia



Passo della maglia costante

Aumentando lo spostamento dello stent sulla parete del tessuto endoteliale aumenta la percentuale di prolasso

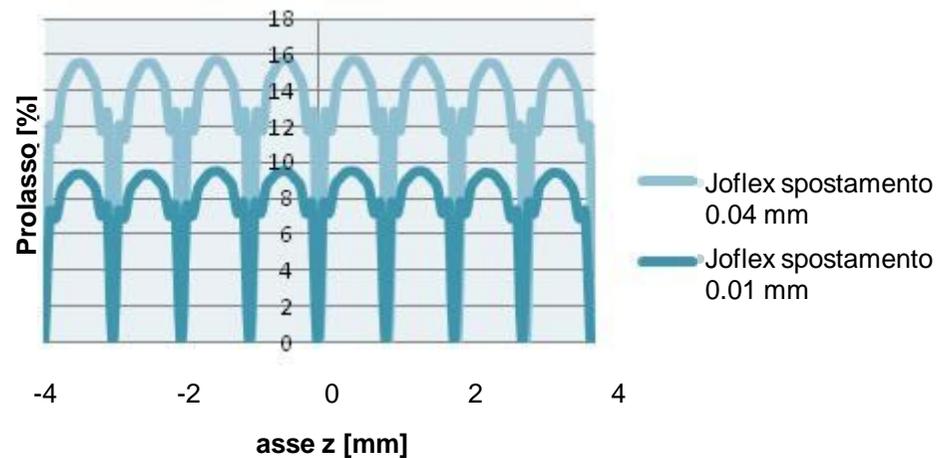


Analisi 2

Conclusioni

Al variare dello spostamento della maglia

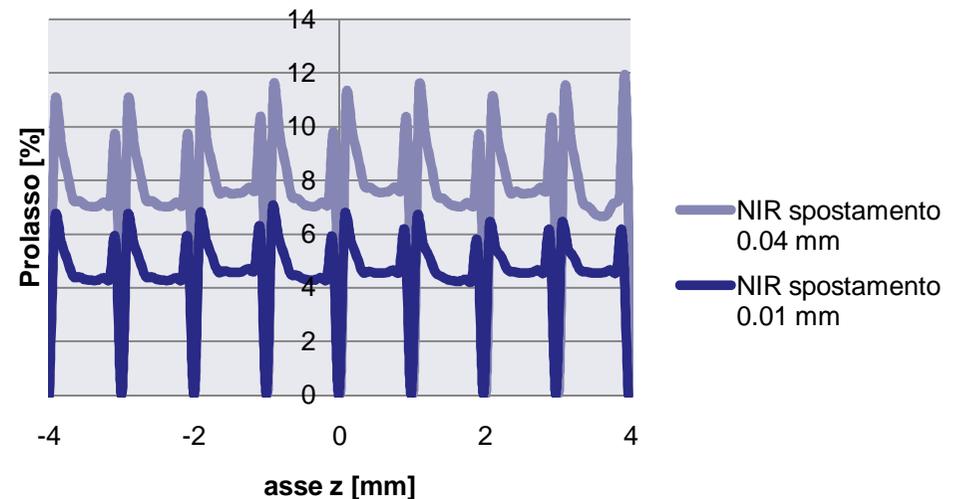
Joflex stent



Passo della maglia costante

Aumentando lo spostamento dello stent sulla parete del tessuto endoteliale aumenta la percentuale di prolasso

NIR stent

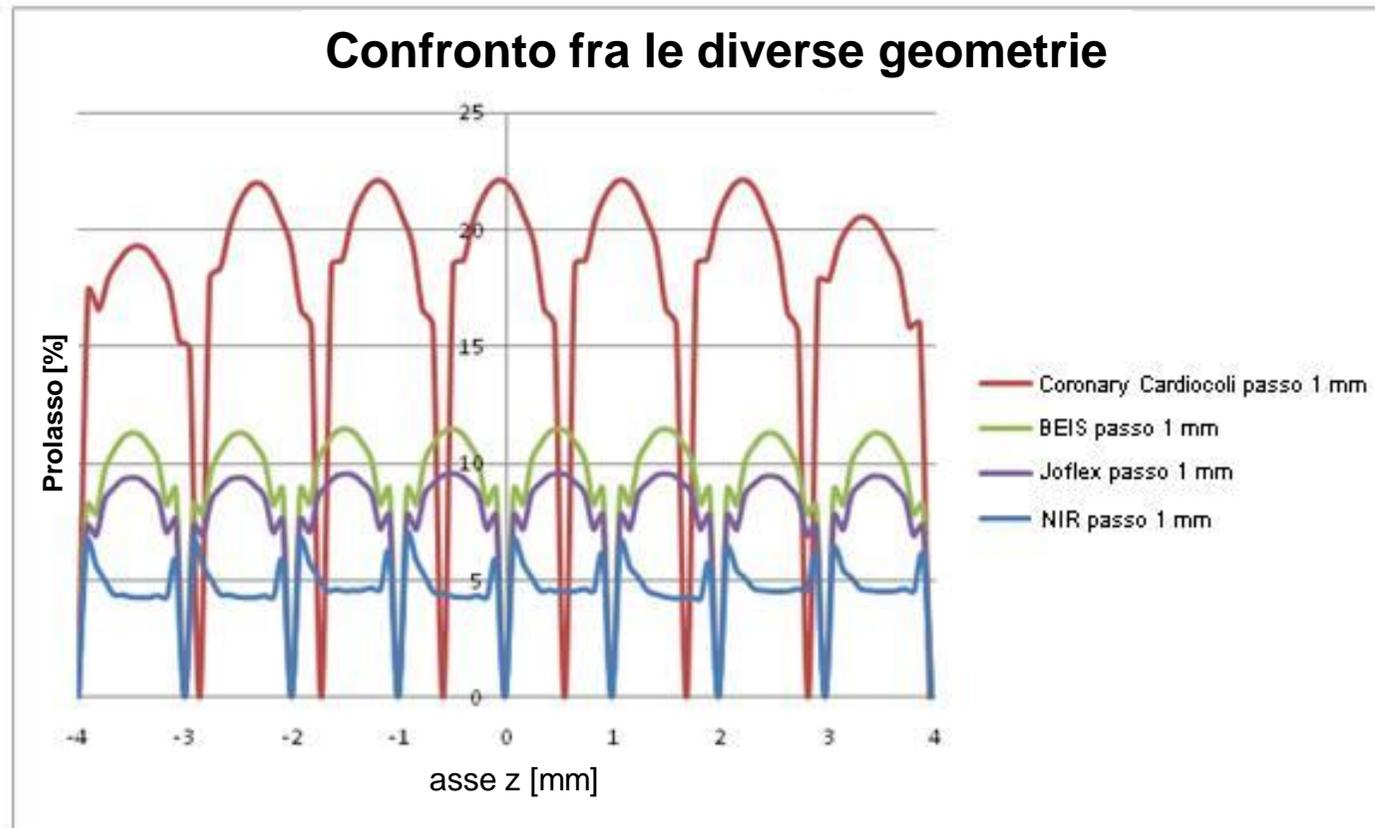


Conclusioni

Passo 1 mm
Spostamento radiale 0.01 mm

Analisi 3

Al variare della tipologia di stent



Il NIR è lo stent che evidenzia una percentuale di prolasso più bassa rispetto ai restanti stent

Il Coronary Cardiocoil, avente una maglia solenoidale, è lo stent che presenta un prolasso maggiore rispetto ai restanti stent

Conclusioni finali

Il prollasso vasale varia al variare della geometria dello stent

La percentuale di prollasso aumenta all'aumentare del carico di prova e del passo dello stent (stent a maglia larga)

Una geometria a maglia più stretta è vantaggiosa poichè consente di ottenere (caso DES) una distribuzione più uniforme ed omogenea dell'agente attivo

SVILUPPI FUTURI

- Comparare i risultati ottenuti con quelli ricavati considerando il modello non lineare iperelastico, i cui moduli elastici sono ricavati dalle curve di stress-strain
- Introduzione delle proprietà di viscoelasticità dell'arteria coronarica, al fine di osservare il comportamento del tessuto a lungo termine

Grazie per l'attenzione ...