

نم خدای

تأثيرات تحريك ميدان الكترومغناطيسي پالسي بر بافت استخوان و غضروف

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بيومكانيك سيستم هاي اسكلتي عضلاني

پس زمینه علمی و ویژگی‌های الکتروفعال بافت‌ها

بافت استخوان

استخوان ماده‌ای کامپوزیتی شامل ۶۵٪ فاز معدنی هیدروکسی‌آپاتیت و ۳۵٪ فاز آلی عمدتاً کلاژن نوع ۱ است که خواص پیزوالکتریک و دی‌الکتریک ذاتی دارد

غضروف مفصلی

غضروف بافتی بدون عروق خونی است که عمدتاً از کندروسیت‌ها و ماتریکس خارج سلولی غنی از کلاژن نوع ۲ و پروتئوگلیکان تشکیل شده و دارای خواص الکتروکینتیک است

اثر پیزوالکتریک

فیبرهای کلاژن در تحریک مکانیکی قطبش الکتریکی ایجاد می‌کنند که در سیگنال‌دهی بیوالکتریک درون‌زا و تنظیم بازسازی بافت نقش حیاتی دارد

میدان‌های الکترومغناطیسی خارجی می‌توانند مکانیسم‌های ترمیم طبیعی بدن را تقویت کنند



دستگاه‌های تحریک PEMF

دستگاه‌های تجاری

دستگاه‌های متعددی در بازار موجود است، از جمله **BIOSTIM** و **I-ONE** ایتالیا
SpinalStim و **PhysioStim** آمریکا که پارامترهای متفاوتی دارند

اصول فنی

دستگاه‌های **PEMF** شامل سلونوئید یا جفت سیم‌پیچ **Helmholtz** هستند که با عبور
جریان متناوب، میدان مغناطیسی متغیر با زمان تولید می‌کنند

- شدت میدان مغناطیسی: ۰.۱ تا ۲۰ میلی‌تسلا
- فرکانس: ۰.۲ تا ۱۵۰ هرتز
- انواع شکل موج: مثلثی، مربعی، سینوسی، دوزنقه‌ای

توصیف گر کمی : دوز PEMF

برای مقایسه پروتکل‌های مختلف **PEMF**، یک معیار جامع به نام دوز **PEMF** معرفی شد که شدت میدان مغناطیسی، شکل موج و مدت زمان قرارگیری را در نظر می‌گیرد

01

محاسبه **Brms**

مقدار میانگین شدت میدان مغناطیسی

02

محاسبه **texp**

مدت کل قرارگیری بافت، سلول یا ارگان در معرض میدان
مغناطیسی

03

فرمول دوز PEMF

$D = Brms \times texp$ (واحد: **$mT \cdot h$**)



این روش برای اولین بار ارائه شده و امکان مقایسه کمی مطالعات مختلف را فراهم می‌کند

مقایسه کمی مطالعات **in vitro** استخوان

آستانه برای **Brms** بالا

برای $Brms \geq 0.3 mT$ ، حداقل دوز $0.2 mT \cdot h$
برای القای اثرات استئوژنیک لازم است

آستانه برای **Brms** پایین

زمانی که **Brms** کمتر از $0.3 mT$ باشد، دوز
PEMF باید حداقل $10 mT \cdot h$ باشد تا اثرات
استئوژنیک مشاهده شود

محدوده پارامترها

Brms: $0.002 mT$ تا 4.5

این یافته‌ها نشان می‌دهد که مدت زمان قرارگیری در شدت‌های پایین نقش حیاتی دارد، در حالی که در شدت‌های بالاتر اهمیت کمتری دارد



مطالعات *in vitro* بر روی بافت غضروف

تأثیر بر MSC

1

بیان ژن‌ها

2

افزایش بیان ***COL2***، ***SOX9***، ***ACAN*** و کاهش بیان فاکتورهای کاتابولیک

تولید ماتریکس

3

تقویت تولید و رسوب ***GAG*** و سنتز ماتریکس غضروف مانند



مقایسه کمی مطالعات *in vitro* غضروف

1

تکثیر کندروسیت

برای دوزهای بیشتر از $3.5 \text{ } mT \cdot h$

تحریک تکثیر موثر است

2

تمایز کندروژنیک

دوزهای بالاتر از $26.02 \text{ } mT \cdot h$ منجر به تمایز

کندروژنیک می شود

3

دوزهای پایین

برای دوزهای کمتر از $3.5 \text{ } mT \cdot h$ ، نتایج متناقض

گزارش شده است

محدوده پارامترها ***Brms***: از 0.25 تا $2.1 \text{ } mT$ و دوز از 2×10^{-2} تا $3 \times 10^{-2} \text{ } mT \cdot h$



مدت زمان قرارگیری به نظر می رسد پارامتر حیاتی برای تمایز کندروژنیک باشد



ترمیم شکستگی استخوان

مطالعات روی خرگوش و موش • بهبود سازمان‌دهی بافت ترمیم شده و افزایش استحکام پس از شکستگی را نشان داده است **PEMF** صحرائی اثربخشی را تأیید کرده‌اند



یکپارچگی ایمپلنت

تحریک **PEMF** تشکیل استخوان اطراف ایمپلنت‌های تیتانیوم را تقویت کرده و بیان ژن‌های استئوژنیک را افزایش می‌دهد



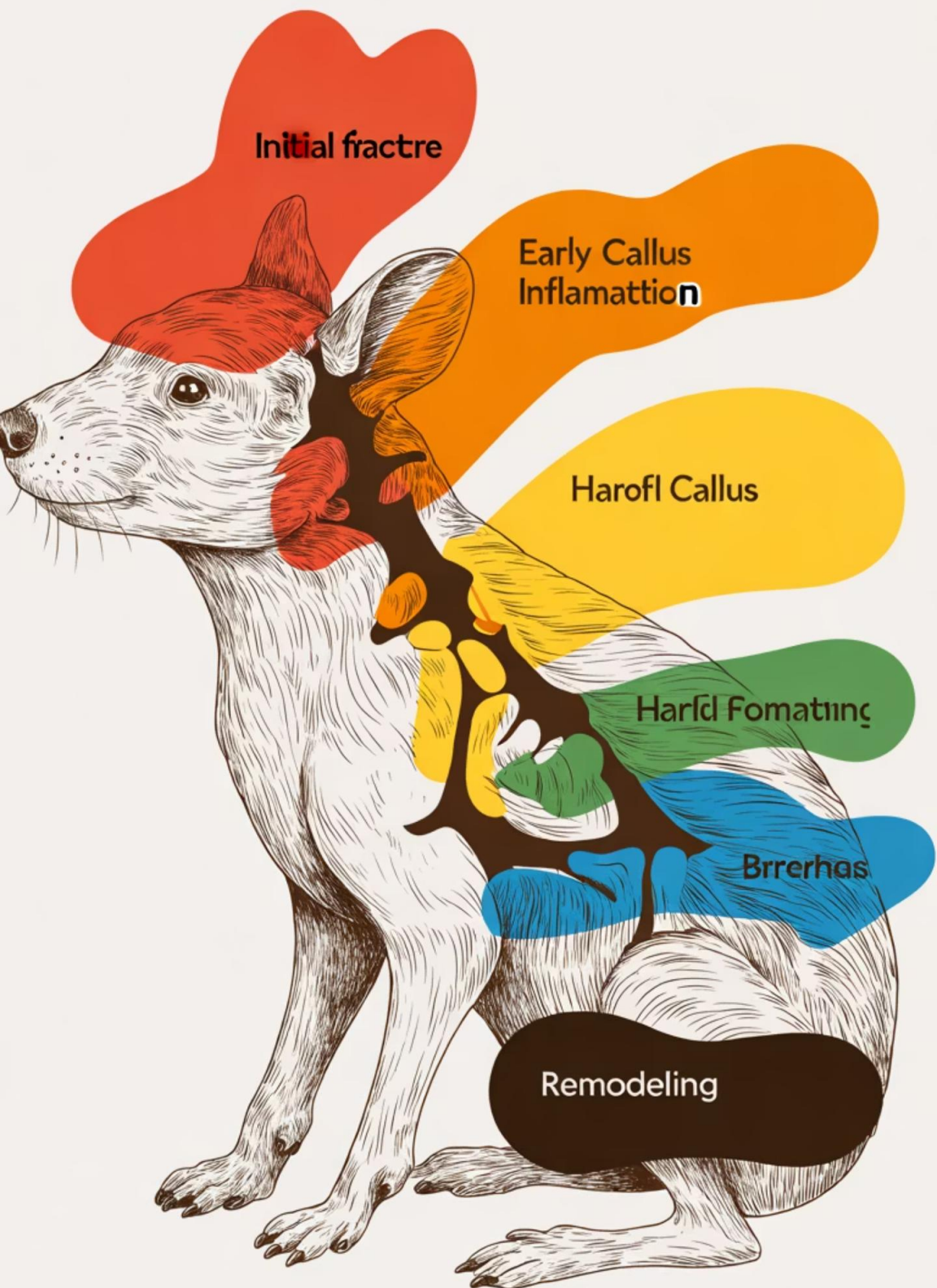
پوکی استخوان

درمان با **PEMF** تراکم استخوانی را حفظ کرده، بدتر شدن ریزساختار استخوانی را مهار می‌کند و از دست دادن استخوان تراکولار را کاهش می‌دهد



آرتروز و غضروف

فرآیندهای دژنراتیو غضروف را کاهش می‌دهد، مسیرهای التهابی را تعدیل کرده و پارامترهای ماتریکس را بهبود می‌بخشد **PEMF**



نتیجه‌گیری و چشم‌انداز آینده

1

وضعیت فعلی

به عنوان مداخله بالینی غیرتهاجمی برای اختلالات استخوان و غضروف پذیرفته **PEMF** شده است، اما استانداردسازی پروتکل‌ها همچنان چالش اصلی است

2

معیار دوز PEMF

معرفی توصیف‌گر کمی دوز **PEMF"** امکان مقایسه مطالعات مختلف و شناسایی آستانه‌های بیولوژیکی را فراهم می‌کند

3

توصیه‌ها برای آینده

تحقیقات آینده باید بر شناسایی پارامترهای بهینه **PEMF**، توسعه پروتکل‌های استاندارد و استفاده از مدل‌های بیومیمتیک واقع‌گرایانه‌تر تمرکز کند

یافته‌های کلیدی

- استخوان $mT \cdot h : Brms < 0.3$ نیاز به دوز $mT \cdot h > 10$ دارد
- استخوان $mT \cdot h : Brms \geq 0.3$ نیاز به دوز $mT \cdot h \geq 0.21$ دارد
- غضروف: دوز $mT \cdot h > 26$ برای تمایز کندروژنیک

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