Comparison of Bite Force with Locking Plates versus Non-Locking Plates in the Treatment of Mandibular Fractures: A Meta-Analysis

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Abstract

Introduction Mandibular fractures represent a high percentage of all facial fractures, and the bite force is a fundamental parameter to measure the actual mandibular function and, subsequently, the masticatory efficiency and quality of life.

Objectives The purpose of the present systematic review was to verify if there is any difference in the bite forces of patients with mandibular fractures fixed by locking or non-locking plates, testing the null hypothesis of no difference in this parameter.

Data Synthesis A systematic review of the literature was conducted using four databases (PubMed, Virtual Health Library, Web of Science and Science Direct) without restrictions as to publication date or language. We found 3,039 abstracts, and selected 4 articles for this review.

Keywords
► bite force
► mandibular fracture
► fracture fixation
► bone plates
► internal fixators

Conclusion The overall results show better performance in bite force for the locking plates when compared with the non-locking plates in the incisor region (mean deviation [MD]: 1.18; 95% confidence interval [95%CI]: 0.13–2.23), right molar region (MD: 4.71; 95%CI: 0.63–8.79) and left molar region (MD: 10.34; 95%CI: 4.55–16.13).

Although the results of this study indicated a better bite force result with the locking plates, there is still no sufficient evidence to support this information safely.

Introduction

Mandibular fractures represent a high percentage of all facial fractures.¹² The most common causes of these injuries are interpersonal violence, falls, lesions practicing sports, and accidents at work and traffic accidents.³ The consequences of mandibular fractures can include malocclusion, temporomandibular joint syndrome, and poor mastication,⁴ leading to a decrease in quality of life.⁵

The mandibular fracture fixation by metallic plates was first described by Michelet in 1973,⁶ and was subsequently improved by Champy in 1975,⁷ who described the ideal places in the mandible to apply plates that could resist to torsional forces during osteosynthesis. The standard plate system works when the heads of the screws compress the plate to the bone to maintain stability, preventing changes in the alignment of the fragments and maintaining occlusal stability.⁸ On the other hand, the locking plate system...
attaches the plates to the bone by locking the screws to both
the bone and the plate, which maintains the stability of the
system. Therefore, treatments with locking plates lead to
fewer changes in occlusal relationships, fewer screw-loosen-
ing events, less problems with bone vascularization, greater
stability between fragments, and easier placement of the
plates when compared with treatments with non-locking
systems.11,12

Some characteristics of the locking plate systems are
recognized as disadvantages, such as the fact that they are
more expensive than the standard systems, and need a
specific apparatus in order to be applied in the bone. Thus,
for each method and instrument launched by new studies, it
is necessary to evaluate the actual advantages and disadvan-
tages, so they may be properly applied in clinical situations.
According to a recent meta-analysis,13 there are no signifi-
cant differences in the postoperative complication rates with
the use of locking plate systems when compared with the use
of standard plate systems in the management of mandibular
fractures, but this study did not assess the bite force mea-
surements. Bite force is a fundamental parameter to measure
the actual mandibular function and, subsequently, the mastic-
tory efficiency and quality of life.

The purpose of the present systematic review was to verify
if there is any difference in the bite force of patients with
mandibular fractures fixed by locking or non-locking plates,
testing the null hypothesis of no difference in this parameter.

Review of the Literature

The present study was conducted according to the Cochrane
Handbook for Systematic Reviews of Interventions (apud
Chrcanovic, 2014),13 and the Preferred Reporting Items for
Systematic Reviews and Meta-Analyses (PRISMA) statement
using the Review manager (RevMan) software, version 5.3 (The
Cochrane Collaboration, Copenhagen). It was registered in
the International Prospective Register of Systematic Reviews
(PROSPERO; CRD42016051937).

We conducted an electronic search to identify relevant
literature published since November 11, 2016, in the
PubMed, the Virtual Health Library (VHL), the Web of Science
and the Science Direct databases. The search was performed
using four different combinations of terms in all databases,
following these stages: stage 1–(mandibular fracture) AND
osteosynthesis AND (bite force); stage 2–(mandibular frac-
ture) AND osteosynthesis AND (occlusal force); stage 3–
(mandibular fracture) AND osteosynthesis AND (masticatory
force); and stage 4–(mandibular fracture) AND (locking plate
OR non-locking plate OR non-locking plate OR standard plate
OR conventional plate).

Furthermore, we also searched the gray literature (Google
Scholar), published theses (http://bancodetesecapes.gov.
br/banco-teses), and the reference lists of all studies identi-
fied as relevant reviews for possible additional studies. We
also searched for relevant ongoing clinical trials in the
Clinical Trials Registry (http://www.clinicaltrials.gov).

The included studies must have reported the criteria for
bite force measurement of the patients and the follow-up
measurements. The exclusion criteria were: textbooks, case
reports, technical reports, review papers, opinion articles,
cover letters, in vitro studies, animal studies, and papers
without available abstracts. After independently reading
paper titles and abstracts, the reviewers checked the results
of the selected papers. Disagreements were resolved by
consensus. The same process was performed when reading
the full text for the final inclusion of the papers in the
systematic review.

After the database search, 3,039 studies were identified.
After removing duplicates, 1,697 studies remained. After
tooling titles and abstracts, we retrieved 25 full-text studies.
The reference lists of the selected papers and a hand search
revealed one additional relevant paper. A total of 4 studies
involving 130 patients4,14–16 evaluated bite force and were
included in the qualitative synthesis (Fig. 1). One study was
mentioned in two separate papers14,16 that reported the same
statistical data. These two articles were thus considered a
single paper for the meta-analysis. One study presented the
results through graphs, and it was not possible to extract the
adequate statistical data for it.15 The author was contacted by
e-mail, but we could not obtain an answer. Therefore, only two
studies4,14 were included in the meta-analyses.

The relevant characteristics of the included studies are
presented in Table 1. All studies evaluated and compared the
bite force of patients treated with locking and non-
locking plates for the osteosynthesis of the mandibular
fractures. The follow-up periods ranged from 1 to 12 weeks.
The number of fractures ranged from 31 to 34. Out of the four
studies, three used the very own patients as controls by
measuring the bite force preoperatively. All plates systems
were 2.0 mm (Table 1). The results were checked by
reviewers after data collection to ensure accuracy.

The quality of the included studies was independently
assessed by the same reviewers using a specific protocol
developed by Higgins & Green (2011, apud Chrcanovic, 2014)
13 for the assessment of the risk of bias. The classification of
the potential risk of bias for each study was based on the
following criteria: sequence generation; allocation sequence
concealment; blinding of participants, personnel, and out-
come assessors; incomplete outcome data; and selective
outcome reporting. Each study was submitted to analysis,
and the criteria were rated as exhibiting low, high, or unclear
(no information or uncertain) risk of bias. The disagreements
between reviewers were resolved by consensus for the final
classification. Our assessment is presented in Fig. 2.

The meta-analysis was performed using the R software (R
Foundation for Statistical Computing, Vienna, Austria), ver-
sion 3.3.1. The packages “meta” and “metafor” were used to
perform the statistician calculation and the forest plots. The
heterogeneity of the results of the studies was assessed using
the I-squared (I²) test. Values above 25% and 50% were
considered indicatives of moderate and high heterogeneity
respectively. As heterogeneity was present (I² > 0) in all
tests, the random effect model was used to perform the
meta-analysis.17,18

The effect estimates were expressed as the weighted
mean difference between the groups, and were obtained
by comparing the baseline mean values at the end of the study for each group.

All studies evaluated the bite forces by the same method, using the indigenous Bite Force Recorder, which consists of four strain gauges mounted on steel bars, forming a Wheatstone bridge. Load changes in the steel bar produced a measurable voltage change across the four strain gauges. All measurements were made with the patient seated with the head upright, in an unsupported natural head position, and looking forward. The patients were instructed to bite on the pads of bite force gauge to the maximal level. The results were analyzed in the follow-ups at 1, 3, 6, and 12 weeks, observing the mean of the bite force measurements in the incisor, left molar, and right molar regions (Table 2).

The results of the meta-analysis showed that when the bite force in the incisor region was evaluated, the patients treated with locking plates showed no difference in bite force when compared with the patients treated with non-locking plates in the first (mean deviation [MD]: 0.84; 95% confidence interval [95%CI]: -0.62–2.30), third (MD: 0.91; 95%CI: -0.29–2.10), and sixth (MD: 1.05; 95%CI: -1.11–3.20) weeks. However, when evaluating the pooled bite force including 3 months of follow-up, the locking plates obtained better results than the non-locking plates for the osteosynthesis of mandibular fractures (MD: 1.18; 95%CI: 0.13–2.23; I² = 57.2%) (Fig. 3).

The patients treated with locking plates showed no difference in bite force in the right molar region in the first (MD: 1.45; 95%CI: -1.24–4.14), third (MD: 1.18; 95%CI: -2.82–5.18) and sixth (MD: 7.47; 95%CI: -6.85–21.78) weeks when compared with the patients treated with non-locking plates. However, the effect of the locking plates considering 3 months of follow-up was better than the effect of the non-locking plates (MD: 4.71; 95%CI: 0.63–8.79; I² = 76.8%) (Fig. 4). Regarding the left molar region, locking plates and non-locking plates did not differ significantly in the first (MD: 5.46; 95%CI: -2.85–13.78), third (MD: 8.16; 95%CI: -5.25; 21.58), and sixth (MD: 12.47; 95%CI: -9.85; 34.79)
The analysis after 3 months of follow-up showed that the locking plates obtained better results for bite force than the non-locking plates for the osteosynthesis of mandibular fractures (MD: 10.34; 95% CI: 4.55–16.13; I² = 89.2%) (Fig. 5).

Discussion

When comparing the use of locking and non-locking plate fixation systems for mandibular fractures, several clinical parameters have already been analyzed and published in two systematic reviews. However, none of these studies compared the bite forces of patients after surgeries that used these plate systems. It has been proved that the bite force is a fundamental factor for masticatory performance, having a significant influence on the patient's quality of life. As the current trend in the treatment of oral and maxillofacial fractures is the early reestablishment of the function of the stomatognathic system, understanding the advantages and disadvantages of these two fixation systems is necessary. The results of the present review suggest that there was no difference in bite force evaluated between the two fracture fixation systems until the sixth week, although a gradual increase in bite force was verified until the third postoperative month in both groups. Nevertheless, better bite force was observed in the groups of locking plates after three months of follow-up. The analysis after 3 months of follow-up showed that the locking plates obtained better results for bite force than the non-locking plates for the osteosynthesis of mandibular fractures (MD: 10.34; 95% CI: 4.55–16.13; I² = 89.2%) (Fig. 5).

Table 1: Characteristics of studies included in the systematic review

| Study         | Country | Mean Age (years) | N (M/F) | Site of mandibular fracture | Number of fractures | Follow-up | Interval (mean) | Control for bite force | Type of plates used | Bite force measurements method |
|---------------|---------|------------------|---------|----------------------------|---------------------|-----------|-----------------|------------------------|----------------------|-----------------------------|
| Agarwal et al | India   | (16–30)          | 20 (19/1)| Parasymphysis             | 34                  | 1, 3, 6 weeks and 3 months | 8.7       | Same patients pre-operatively | Synthes (West Chester, Pennsylvania, US) 2-mm locking titanium miniplates and Synthes 2-mm non-locking titanium miniplates | Indigenous Bite Force Recorder |
| Kumar et al   | India   | 27.2             | 20 (18/2)| Body of mandible          | ND                  | 7, 14, 21, 28, and 90 days | 7.4       | Same patients pre-operatively + healthy patients (control group) | Single 4-hole, stainless steel locking miniplate and two 4-hole, stainless steel conventional miniplates (2.0 mm system, SK Surgicals, Pune, Maharashtra) | Indigenous Bite Force Recorder |
| Giri et al    | India   | (11–20)          | 20 (17/3)| Parasymphysis             | 31                  | 1, 3 and 6 weeks | 7.5       | Same patients pre-operatively | 2-mm locking titanium miniplates and 2-mm standard titanium miniplates | Indigenous Bite Force Recorder |
| Rastogi et al | India   | (11–40) min-max  | 20 (17/3)| Parasymphysis             | 31                  | 1, 3 and 6 weeks | 5         | Same patients pre-operatively | 2-mm locking miniplates and 2-mm standard miniplates | Indigenous Bite Force Recorder |

Abbreviations: F, female; M, male; N, number of included patients; ND, not declared.

Notes: ‘/C3’ The area of the mandible most affected by fractures; ‘/C3/C3’ Interval between the moment of the injury and the treatment in days.
of follow-up. These results enable us to imply that the locking plate system promotes the reestablishment of masticatory functions earlier than the non-locking plate system. This may be due to the locking plate system’s ability to join the fragments of the fracture without leaving gaps.\(^1\) In the non-locking plates system, the existence of these gaps enables the formation of bony callus between the fragments of the fracture, delaying the repair process and thus reducing the effectiveness of this system.\(^2\)

Four articles met the inclusion criteria for this study.\(^3\) Two of these articles presented identical results;\(^4\) another study included in this review expressed the results in graphs, so it was not included in the meta-analysis due to the impossibility of extracting raw data such as mean and standard deviation.\(^15\) Despite the possibility of performing a meta-analysis with only two studies,\(^16\) this is a limitation of this study. The lack of studies is justified by the fact the other studies that investigated bite force comparing locking and non-locking plate systems were laboratory studies using finite element analysis,\(^26\) ex vivo human\(^27\) or animal\(^28\) parts, or a combination of methods,\(^29\) and they failed to meet the inclusion criteria adopted in this review.

In order to evaluate the bite force, one could use a dynamometer,\(^30\) a bite fork,\(^31\) or the indigenous Bite Force Recorder, which was used in all the studies included in this review.\(^4\)\(^14\)–\(^16\)

In addition to the diversity of methods for measuring bite force, there is also no established standard anatomical sites used for this purpose.\(^30\),\(^31\) In this systematic review, all studies performed the measurement of bite force in the incisor, left molar and right molar regions, in agreement with the studies by Gupta and colleagues (2012) and Kshirsagar and colleagues (2011).\(^32\),\(^33\)

To avoid possible biases and facilitate the comparison among future studies, a single measurement of bite force

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### Table 2 Data extracted from the included studies (mean and standard deviation of bite forces)

| Follow-up | Incisor region: Mean ± SD | Left molar region: Mean ± SD | Right molar region: Mean ± SD |
|-----------|---------------------------|------------------------------|-------------------------------|
|           | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking |
| Author, year |                           |                              |                                 |                                 |                     |                     |                     |                     |
| Agarwal et al\(^4\) | 2.47 ± 1.74 | 0.90 ± 0.91 | 14.6 ± 6.30 | 4.73 ± 3.74 | 8.39 ± 5.72 | 5.55 ± 3.68 |
| Giri et al\(^14\) | 5.54 ± 1.67 | 5.46 ± 1.22 | 19.83 ± 2.19 | 18.00 ± 4.97 | 19.5 ± 2.17 | 19.34 ± 4.99 |
| Kumar et al\(^15\) | ND | ND | ND | ND | ND | ND |
| Rastogi et al\(^16\) | 5.54 ± 1.67 | 5.46 ± 1.22 | 19.83 ± 2.19 | 18.00 ± 4.97 | 19.5 ± 2.17 | 19.34 ± 4.99 |

| Follow-up | Incisor region: Mean ± SD | Left molar region: Mean ± SD | Right molar region: Mean ± SD |
|-----------|---------------------------|------------------------------|-------------------------------|
|           | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking |
| Author, year |                           |                              |                                 |                                 |                     |                     |                     |                     |
| Agarwal et al\(^4\) | 4.22 ± 2.45 | 2.61 ± 1.75 | 27.79 ± 11.85 | 12.23 ± 5.94 | 20.52 ± 9.58 | 15.26 ± 9.69 |
| Giri et al\(^14\) | 7.26 ± 1.96 | 6.85 ± 1.59 | 19.83 ± 2.19 | 18.00 ± 4.97 | 19.5 ± 2.17 | 19.34 ± 4.99 |
| Kumar et al\(^15\) | ND | ND | ND | ND | ND | ND |
| Rastogi et al\(^16\) | 7.26 ± 1.96 | 6.85 ± 1.59 | 19.83 ± 2.19 | 18.00 ± 4.97 | 19.5 ± 2.17 | 19.34 ± 4.99 |

| Follow-up | Incisor region: Mean ± SD | Left molar region: Mean ± SD | Right molar region: Mean ± SD |
|-----------|---------------------------|------------------------------|-------------------------------|
|           | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking |
| Author, year |                           |                              |                                 |                                 |                     |                     |                     |                     |
| Agarwal et al\(^4\) | 7.93 ± 4.94 | 5.17 ± 2.41 | 43.27 ± 13.80 | 18.99 ± 6.08 | 37.92 ± 10.44 | 22.73 ± 7.40 |
| Giri et al\(^14\) | 8.83 ± 1.97 | 8.49 ± 1.39 | 22.69 ± 2.09 | 21.20 ± 5.70 | 23.64 ± 3.02 | 23.08 ± 5.99 |
| Kumar et al\(^15\) | ND | ND | ND | ND | ND | ND |
| Rastogi et al\(^16\) | 8.83 ± 1.97 | 8.49 ± 1.39 | 22.69 ± 2.09 | 21.20 ± 5.70 | 23.64 ± 3.02 | 23.08 ± 5.99 |

| Follow-up | Incisor region: Mean ± SD | Left molar region: Mean ± SD | Right molar region: Mean ± SD |
|-----------|---------------------------|------------------------------|-------------------------------|
|           | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking | Locking | Non-locking |
| Author, year |                           |                              |                                 |                                 |                     |                     |                     |                     |
| Agarwal et al\(^4\) | 16.76 ± 9.34 | 6.95 ± 2.02 | 63.07 ± 21.30 | 28.69 ± 7.42 | 58.43 ± 20.25 | 31.58 ± 9.58 |
| Giri et al\(^14\) | ND | ND | ND | ND | ND | ND |
| Kumar et al\(^15\) | ND | ND | ND | ND | ND | ND |
| Rastogi et al\(^16\) | ND | ND | ND | ND | ND | ND |

Abbreviations: ND, not declared; SD, standard deviation.
### Study Details

**Fig. 3** Forest plot for the bite forces in the incisor region. Abbreviations: 95% CI, 95% confidence interval; MD, mean deviation; SD, standard deviation.

| Study          | Experimental Total | Mean | SD  | Control Total | Mean | SD  | Mean difference | MD   | 95% CI (random) |
|----------------|--------------------|------|-----|---------------|------|-----|-----------------|------|-----------------|
| **follow-up = 1st week** |                    |      |     |               |      |     |                 |      |                 |
| Agarwal et al | 10                 | 8.39 | 5.72| 10            | 5.55 | 3.68| 2.84            | 2.84 | [-1.38–2.06]    | 17.2% |
| Giri et al   | 10                 | 16.60| 3.45| 10            | 16.10| 4.46| 1.45            | 1.45 | [-1.24–4.14]    | 35.4% |
| Random effects model | 20      |      |     | 20            |      |     |                 |      |                 |
| Heterogeneity: |                    |      |     |               |      |     |                 |      |                 |
| I-squared:    | 0%                  |      |     |               |      |     |                 |      |                 |
| tau-squared:  | 0                   |      |     |               |      |     |                 |      |                 |
| p:            | 0.4023              |      |     |               |      |     |                 |      |                 |

### Study Details

**Fig. 4** Forest plot for the bite forces in the right molar region. Abbreviations: 95% CI, 95% confidence interval; MD, mean deviation; SD, standard deviation.

| Study          | Experimental Total | Mean | SD  | Control Total | Mean | SD  | Mean difference | MD   | 95% CI (random) |
|----------------|--------------------|------|-----|---------------|------|-----|-----------------|------|-----------------|
| **follow-up = 1st week** |                    |      |     |               |      |     |                 |      |                 |
| Agarwal et al | 10                 | 10   | 0.90| 10            | 5.46 | 1.22| 0.08            | 0.08 | [-1.20–1.36]    | 19.8% |
| Giri et al   | 10                 | 20   |     | 20            |      |     |                 |      |                 |
| Random effects model | 20      |      |     | 20            |      |     |                 |      |                 |
| Heterogeneity: |                    |      |     |               |      |     |                 |      |                 |
| I-squared:    | 63.4%               |      |     |               |      |     |                 |      |                 |
| tau-squared:  | 0.7034              |      |     |               |      |     |                 |      |                 |
| p:            | 0.0895              |      |     |               |      |     |                 |      |                 |

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would enable a better evaluation of the performance of the plate systems, since there is no significant difference in the bite force in the fractured side and the non-fractured side because, in the immediate postoperative period, there is a reduction in this force caused by protective neuromuscular mechanisms. This single measurement could further help control the bias of measuring the bite forces of one edentulous side and another toothed side. In addition, it is suggested that the maximum bite force would be obtained after at least three attempts, since the first attempt at measuring should be considered a stage of adaptation to the technique by the patient. Some clinical parameters such as infection, malocclusion, hardware failure, wound dehiscence, paresthesia and pain may decrease the bite force of patients treated after mandibular fractures. Although it is difficult to establish what would be a short follow-up period following osteosynthesis surgeries, these factors may have contributed to the fact that in the follow-ups of only a few weeks after surgery there were no significant differences in the means of the bite forces in the regions evaluated when comparing the fixation plates systems. This suggests that the success of the treatment is more related to bone quality, fracture site and surgical technique than to the type of plate system. This is a limitation that must be recognized in this review. Although the studies state that most of the treated fractures have occurred in the symphysis and mandibular parasympysis regions, standardization cannot be achieved due to the peculiarities of each type of fracture. Other limiting factors that may influence the results of this review are the size of the plates and the size of the screws used in each type of fracture. Since there was some standardization during data collection for the bite force variable in the studies included in this meta-analysis, the high heterogeneity present in this review can be attributed to the variability of osteosynthesis techniques due to the peculiarity of each type of mandibular fracture treated.

The literature points to a higher financial cost of the locking system in relation to the non-locking system. However, it is possible that this cost difference is compensated by the increase in bite force in the third month of follow-up, and by the decrease in postoperative complications associated with the locking system. Cost-effectiveness studies are needed to compare the costs of each fracture fixation system with its respective impact on clinical outcomes, and to identify the best alternative for the treatment. The current review presents a summary of the effect of the measures regarding the bite force of patients treated with locking and non-locking plates, which may contribute to the validity of future economic analyzes.

**Final Comments**

There are some limitations to this study that cause these results to be evaluated with discretion. First, a limited number of articles were included in this review. Then, these articles presented unclear results on most bias risk criteria (according to the Cochrane Handbook for Systematic Reviews of Interventions) and an unadjusted presentation of the
results. For a better consistency of the presented evidences, it is suggested that more clinical trials should be performed to evaluate the bite force, measuring the whole mouth in a single time, or even using electromyographic analysis to avoid possible biases. In addition, greater standardization of fracture site, and size of plates and screws used would increase the homogeneity of the results. Using the patient as his or her own control is also a way to standardize the analysis of the results in a more reliable way, which was not done by one of the four included studies. Once statistical significance was found only at the 3-month follow-up, a longer follow-up period should be considered in the next experiments, considering a reduced interval between the measurements in order to accurately estimate the moment of return to functional normality. Although the results of this study indicated a better bite force result with the locking plates, there is still no sufficient evidence to support this information safely.

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